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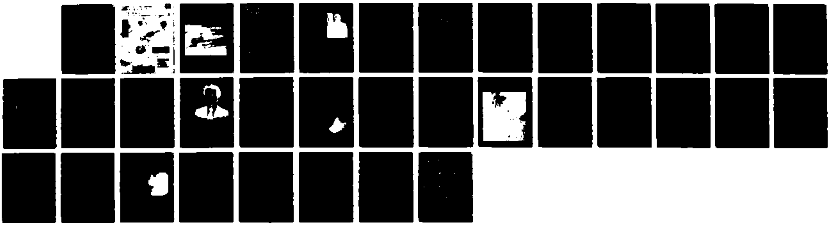

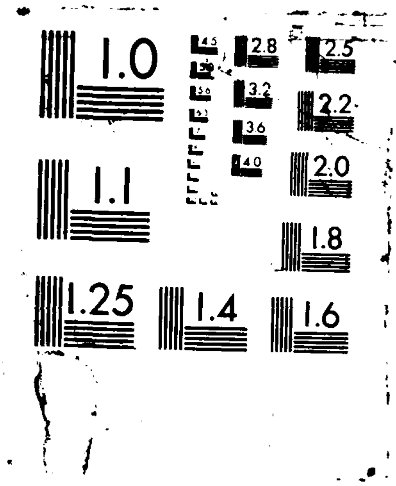
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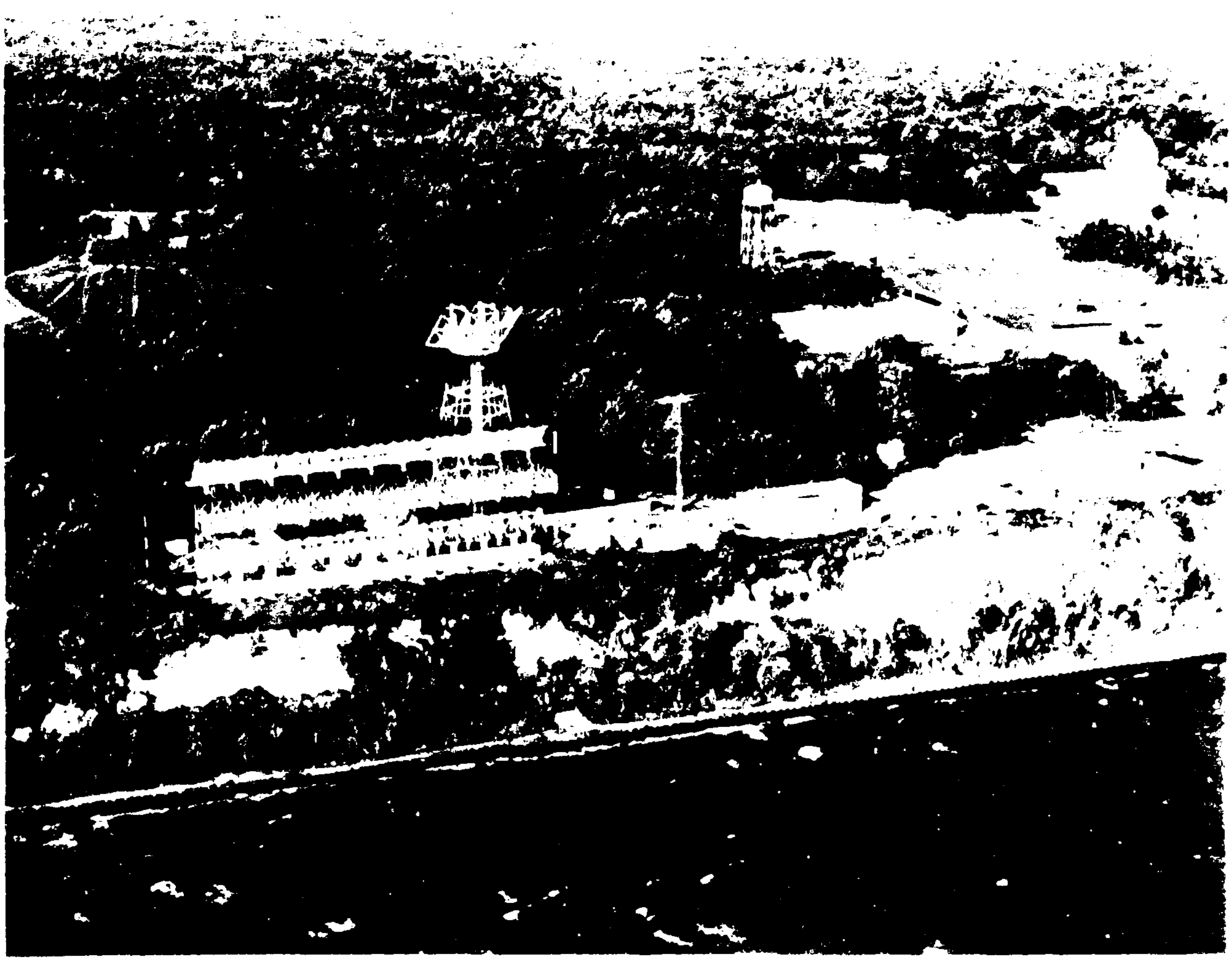
Over-The-Horizon Radar



Photograph of the Chesapeak Bay Detachment of the Naval Research Laboratory (NRL) taken in 1961, showing the powerful radar equipment. This was an important facility in developing techniques and transmitting signals in the early days of Over-the-Horizon (OTH) radar.

In the Mid 1950's, while reading of German WWII electromagnetic backscatter measurements in the high frequency radio spectrum , Dr. Sidney Reed of the Office of Naval Research realized that perturbations in the ionosphere might also give useful backscatter signals. Two quick ONR experiments followed. The NRL "Music" 26MHz radar saw signals from the Nevada Test Site. A 10 to 15 MHz antenna at Patuxent NAS, Maryland, saw signals from Cape Canaveral missile launches. Now 30 years later, with the advent of better signal processing techniques, OTH radars are used to track aircraft and ships, and to monitor the ocean environment, all at ranges of thousands of miles. Both the US and USSR are today making massive investments in OTH radars.

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Articles

Departments

NAVSO P 510

About the Cover

Photo of the Eastern Pacific, which was taken August 17, 1972 by Geostationary Satellite for the Naval Environmental Prediction Research Facility (NEPRF). Among the goals of NEPRF are improving techniques for the processing, display, and utilization of environmental satellite data in support of Fleet operations.

Photo of Super Typhoon Bess (inset), taken September 21, 1971 by High Resolution Visible Image (DMSP) Satellite. *(See article beginning on page 22).*

Naval Research Reviews publishes articles about research conducted by the laboratories and contractors of the Office of Naval Research and describes important naval experimental activities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 732, Office of Naval Research, Arlington, Va. 22217-5000. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. *Naval Research Reviews* is published from appropriated funds by authority of the Office of Naval Research in accordance with Navy Publications and Printing Regulations NAVSO P-35.

Rear Admiral John R. Wilson, Jr., USN Chief of Naval Research

RADM Wilson, a native of Glendale, California, enlisted in the Navy in 1950. Subsequently entering the Naval Academy, he received his commission in 1955 and was designated a naval aviator in October 1956. Promoted to Rear Admiral in December 1986, he became the 16th Chief of Naval Research (CNR) in September 1987.

His first sea duty assignments were with Fighter Squadrons VF-112 and VF-53 deployed to the Far East in *USS Ticonderoga*. After a tour as Aide and Flag Lieutenant to Commander, Carrier Division Four, he served as Operations Officer of VF-14, making deployments to Vietnam and the Mediterranean. In 1970, he became Executive Officer of VF-142, and commanded the "GHOSTRIDERS" from April 1971 to May 1972, completing his second combat tour to Vietnam. RADM Wilson assumed command of Carrier Air Wing 14 during the first deployment of the F-14 and, S-3A and participated in the final operations of the Vietnam action. He later commanded the replenishment ship *USS Kansas City* and then became Commander, Service Squadron Three.

RADM Wilson's shore tours have included two assignments at the Naval Air Test Center, Patuxent River, Maryland, and the Pacific Missile Test Center, Point Mugu, California, where he headed the Joint Evaluation Team for the prosecution of the weapon systems and guided missile trials of the F-14A/Phoenix. In his second tour of duty on the Staff, Naval Air Forces, Pacific Fleet, he served as Chief of Staff and was selected to the rank of Commodore in 1981. He then acted as Director of Logistics and Security Assistance, U.S. Pacific Command, and in July 1984, assumed command of the Pacific Missile Test Center. At the Naval Air Systems Command he served as Director, Air Launched Guided Missile Branch, Deputy Assistant Commander for Navy Ranges and Field Activity Management, and in November 1986, became Assistant Commander for Systems and Engineering, the position held prior to becoming CNR.

A veteran of over 4,500 hours in 104 different aircraft, RADM Wilson has made more than 1,000 carrier arrested landings. He was the first pilot to fire all four air-to-air weapons from the F-14 Tomcat fighter and the only pilot to fire six missiles simultaneously against six separate targets.

As CNR, RADM Wilson oversees the Office of Naval Research, the Office of Naval Technology, the CNR field laboratories and facilities in Washington, D.C., California and Mississippi, and numerous support activities, including science liaison offices in Tokyo and London.

RADM Wilson is a graduate of the Naval Test Pilot School and the Armed Forces Staff College. He is a designated Aeronautical Engineering Specialist and Material Professional with a M.S. in systems management. His military decorations include 20 personal decorations, three unit citations, and 13 service medals.

RADM Wilson is married to the former Connie Dale of Wheat Ridge, Colorado. They have four children: Skip, Robin, Bill and Julie.

Message From Rear Admiral John R. Wilson, Jr., USN

As I assume my new duties as the 16th Chief of Naval Research, I look forward to the exciting challenges and accomplishments that lie ahead. I believe the Office of the Chief of Naval Research is a superb staff of highly motivated specialists in science, technology, contracts, controllership, patents and other support functions. The scientific research accomplishments of our organization are evident in the many advanced Navy systems in the Fleet today and a reputation created through years of imaginative research by the most eminent scientific talent throughout the country.

A former Vice President of General Motors, the late Charles F. Kettering, described basic research as "something, that if you don't do it until you have to, it's too late." For 41 years, the Chiefs of Naval Research and their staff insured that when our Navy needed "it," we had it. Basic research is fundamental to our strength as a Navy and as a nation. The Navy today is a tribute to the foresight of those who have served before me in providing that basic research. How well we are able to meet an increasingly capable threat in the future will be a measure of the continued commitment and vision of those who serve today. Together we will carry out the mandate of the Office of the Chief of Naval Research.

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FUTURE OF BRAIN AND INFORMATION RESEARCH

By Leon N. Cooper
Brown University

Dr. Leon Cooper's article is based on a lecture he presented at the symposium honoring the 40th anniversary of the Office of Naval Research. Many readers will recognize Dr. Cooper as the scientist who in 1972 shared the Nobel Prize with Drs. John Bardeen and J. Robert Schrieffer for his work on the atomic basis of superconductivity. In fact, the two electrons that are linked together and act as a single particle to help achieve the phenomenon of superconductivity have been dubbed "cooper pairs."

Why did a theoretical physicist become involved in a discipline as "soft" as neuroscience? Dr. Cooper believes that some of the most interesting and tractable questions that remain in science center around the abilities of the human brain to acquire, store, and retrieve information. He has successfully devoted the last ten years of his professional life to these problems. The work that Dr. Cooper describes in his paper stems from collaborative research at Brown University and funded for five years through an OCNR Accelerated Research Initiative on learning and memory. Dr. Cooper's contribution epitomizes the kind of first-rate interdisciplinary research that ONR will continue to support in the future.

Joel L. Davis
Biological Sciences Division, ONR

It is an honor as well as a great pleasure to have the opportunity to participate in this 40th anniversary celebration. Since its inception the Office of Naval Research has been extraordinarily influential in shaping and sustaining this country's scientific research.

Predicting the future, as we all know, is risky. Predicting the consequences of scientific research is downright hazardous. What may be most predictable about the benefits of scientific research is its unpredictability. There are certain projects that should clearly be supported. Among these, in the immediate past, one would certainly list lasers and superconductors; and the Office of Naval Research has been heavily involved in the support of such projects. But who in the 1930's would have predicted that among the consequences of the uncertainty principle would be transistors, silicon chips, and all of the vast array of solid state devices on which all modern computers depend? Or that among the consequences of superconductors would be sensitive detectors of magnetic fields now carried on many naval ships. (If some had this vision, I was not among them in 1957.) Or, in the late 19th century, that among the consequences of the research of Maxwell, Lorentz and Einstein, would be all that we call modern communication: radio, radar, etc?

In times of budget deficits and great cost consciousness there is a tendency to become very conservative, to weigh immediate and foreseeable gains against money spent. But if rigid budgetary criteria had been applied in the past, we might today be much the poorer.

In 1887 Edward Bellamy (looking backward from the Utopia he was visiting) wrote:

> . . . if we could have devised an arrangement for providing everybody with music in their homes, perfect in quality, unlimited in quantity, suited to every mood, and beginning and ceasing at will, we should have considered the limit of human felicity already attained, and ceased to strive for further improvements.

Imagine that Her Majesty's Royal Bureau of Marine Research had adopted the goal of music in the average Englishman's home as their criterion for the support of research. It would have been difficult for even the most ingenious program officer to justify continued funding of Maxwell, Lorentz or Einstein. What money was available (budgets being very tight) would likely have been poured into the development of existing technology. As a result of this program our museums might now display a marvelous proliferation of music boxes or piano players.

As we all know, the problem of how to allocate limited research funds is not an easy one. There is no simple recipe. A recent ONR report, *Return on Investment in Basic Research*, (Bruce S. Old Associates, Inc., Concord, Massachusetts, November 1981) suggests that such funds be regarded as investment rather than support. It then follows that, as for other investments, we must reserve some portion for the longer term. We must balance support for projects with easily foreseeable results with support to those people from whom great new ideas may reasonably be expected to come and to young investigators so they have a chance to get started.

Regarded in this light, I can say, without the exaggeration that is permitted on occasions such as this, that the research investments of the Office of Naval Research have been extraordinary. Calculated on the basis of economic return (if naval officers were not so selfless) you would be very rich indeed.

The day may be past when Felix Bloch was able to obtain ONR support for his early work in nuclear magnetic resonance with a one sentence proposal to do solid state research. And one cannot every day have an ONR technical report that later becomes Fritz London's first volume on superfluids. Not every project can result in inventions such as Jay Forrester's magnetic core memory or have among its spin-offs companies such as Digital Equipment Corporation that (as of 1981) had already paid over six hundred million dollars in taxes (the total government investment in the Whirlwind Project was 17.4 million dollars).

But such are the difficult-to-foresee benefits of scientific research conducted by scientists motivated to succeed, allowed to follow what appear to them the most fruitful directions, and unburdened by excessive management. I believe that one of the reasons for its proud record is that the Office of Naval Research has understood very well that a research scientist is like the captain of a ship. To become either, a difficult path must be travelled. But once there, to be effective, both must have the best men and material and must be given freedom of maneuver on the firing line without excessive bureaucratic control.

My main task today is to discuss the current status of work on the brain and make some guesses as to what the future holds for this field. I would like to present a brief summary of some recent theoretical and experimental results related to plasticity in visual cortex, and presumably related to the changes that take place in the nervous system when learning occurs and when memory is stored. Much of this work has been done at Brown University supported by the ONR Special Focus Program on Learning and Memory. More important than the details, I hope to convince you that what is being presented provides us with a language in which questions concerning memory and learning can be discussed with clarity and precision

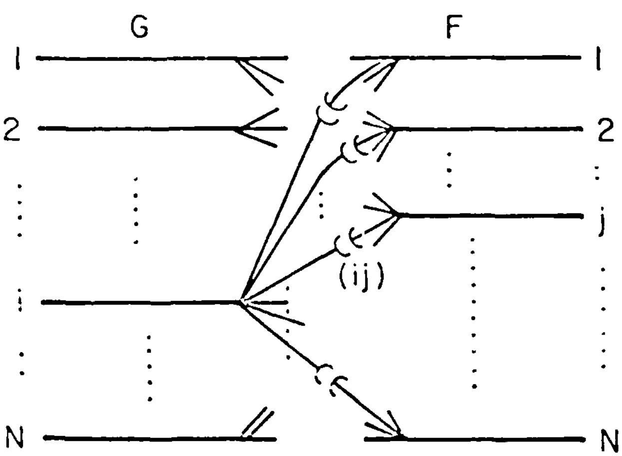
That most intriguing aspect of human memory: its persistence in spite of continual loss of individual neurons over the lifetime of the individual has led many workers to the concept of distributed memory.[1,2,3,4,5,6,7] For a distributed memory (more like a hologram than a photograph) possesses in a very natural way the property of relative invulnerability to the loss of storage units: individual memory sites hold superimposed information concerning many events. In order to obtain a single event, information must be gathered from many sites. Loss of individual units decreases signal-to-noise ratios but does not lose items of information.

Further, in contrast to modern computers that perform large numbers of sequential operations very rapidly and very accurately, the central nervous system works slowly and probably not with enormous accuracy on the level of individual units, with cycle times that cannot be shorter than a few milliseconds. However we can make complex decisions in small parts of a second. This suggests very strongly that there is much parallel processing in the brain—an idea that is almost obvious on inspection of a component such as the retina.

It is now commonly thought that the synaptic junction may be a means to store information (memory, for example) as well as to transmit it from neuron to neuron. Large networks of neurons connected to other neurons via modifiable synaptic junctions provide the physiological substrate for the distributed parallel systems discussed here (Figure 1).

Figure 1

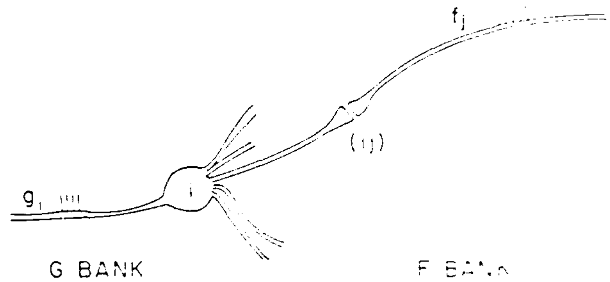
An Ideal Distributed Mapping. Each of the N input neurons in F is connected to each of the N output neurons in G by a single ideal junction. (Only the connections to i are drawn).



The actual synaptic connections between one neuron and another are generally complex and redundant: we have idealized the network by replacing this multiplicity of synapses between axons and dendrites by a single ideal junction which summarizes logically the effect of all of the synaptic contacts between the incoming axon branches from neuron j in the F bank and the dendrites of the outgoing neuron i in the G bank (Figure 2).

Figure 2

An ideal synaptic junction.



Although the firing rate of a neuron depends in a complex and nonlinear fashion on the presynaptic potentials, there is usually a reasonably well-defined linear region in which some very interesting network properties are already evident. We therefore focus our attention on the region above threshold and below saturation for which the firing rate of neuron i in G, g_i, is mapped from the firing rates of all of the neurons f_j in F by:

$$g_i = \sum_{j=1}^{N} A_{ij} f_j \qquad (1)$$

In doing this we are regarding as important average firing rates, and time averages of the instantaneous signals in a neuron (or perhaps a small population of neurons). We are further using the known integrative properties of neurons.

We may then regard $[A_{ij}]$ (the synaptic strengths of the N^2 ideal junctions) as a matrix or a mapping which takes us from a vector in the F space to one in the G space. This maps the neural activities $f = (f_1, f_2, \ldots, f_N)$ in the F space into the neural activities $g = (g_1, \ldots, g_N)$ in the G space and can be written in the compact form:

$$g = Af. \qquad (2)$$

It has been shown that the non-local mapping A can serve in a highly precise fashion as a memory that is content addressable and in which 'logic' is a result of association and an outcome of the nature of the memory itself.

The N^2 junctions, A_{ij}, contain the content of the distributed memory. It could be that a particular junction strength, A_{ij}, is composed of several different components

with different lifetimes thought of as corresponding to different physiological or anatomical effects (e.g., changes in numbers of presynaptic vesicles, changes in numbers of postsynaptic receptors, changes in Ca^{++} levels and/or availability, anatomical changes such as might occur in growth or shrinkage of spines). We then have the possibility that the actual memory content (even in the absence of additional learning) will vary with time. For a two-component system we might have:

$$A_{ij}(t)=A_{ij}^{(long)}(t)+A_{ij}^{(short)}(t), \tag{3}$$

where $A_{ij}(t)$ represents the memory at some time t, while $A_{ij}^{(long)}$ and $A_{ij}^{(short)}$ have long and short lifetimes. Thus in time $A_{ij}^{(short)}$, will decay, leaving $A_{ij}(t)=A_{ij}^{(long)}$. Whether what is in the short-term memory component is transferred to the long-term component might be determined by some global signal, depending on the interest of the information contained in the short-term component.

From this point of view the site of long and short-term memory can be essentially identical. At any given time there is a single memory. The distinction between long and short-term memory is contained in the lifetime of the different components of A_{ij}.

We now ask how a mapping of the type A might be put into the network. The ijth element of A,

$$A_{ij}=\sum_{\mu\nu} c_{\mu\nu}\, g_i^{\mu}\, f_j^{\nu}, \tag{4}$$

is a weighted sum over the j components of all mapped signals f^{ν} and the i components of the responses g^{μ} appropriate for recollection or association. Such a form could be obtained by additions with each input f and output g to the element A_{ij}:

$$\delta A_{ij} \sim g_i\, f_j. \tag{5}$$

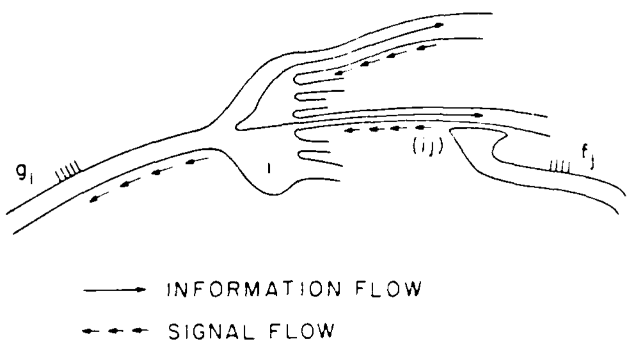
This δA_{ij} is proportional to the product of the differences between the actual and the spontaneous firing rates in the pre and postsynaptic neurons i and j. [This is one realization of Hebb's form of synaptic modification.[8]] The addition of such changes to A for all associations $g^{\mu} \times f^{\nu}$ results finally in a mapping with the properties discussed in the previous section.

Synaptic modification dependent on inputs alone, of the type already directly observed in Aplysia,[9] is sufficient to construct a simple memory – one that distinguishes what has been seen from what has not, but does not easily separate one input from another. To construct a mapping of the form above, however, requires synaptic modification dependent on information that exists at different places on the neuron membrane: what we call two-(or higher-)point modification.

In order that this take place, information must be communicated from, for example, the axon hillock to the synaptic junction to be modified. This implies the existence of a means of internal communication of information within a neuron – in the above example, in a direction opposite to the flow of electrical signals.[5] The junction ij, for example, must have information of the firing rate f_j (which is locally available) as well as the firing rate g_i, which is somewhat removed (Figure 3). One possibility could be that the integrated electrical signals from the dendrites produce a chemical or electrical response in the cell body which controls the spiking rate of the axon and at the same time communicates (by backward spiking, for example) to the dendrite ends the information of the integrated slow potential.

Figure 3

Two Point Modification.



The discussion above leads to a central issue: what is the principle of local organization that, acting in a large network, can produce the observed complex behavior of higher mental processes? There is no need to assume that such a mechanism – believed to involve synaptic modification – operates in exactly the same manner in all parts of the nervous system or in all animals. However, one would hope that certain fundamental similarities exist so that a detailed analysis of the properties of this mechanism in one preparation would lead to some conclusions that are generally applicable. We are interested in visual cortex because the vast amount of experimental work done in this area of the brain – particularly area 17 of cat and monkey – strongly indicate that one is observing a process of synaptic modification dependent on the information locally and globally available to the cortical cells.

Experimental work of the last generation, beginning with the path-breaking work of Hubel and Wiesel,[10, 11] has shown that there exist cells in visual cortex (areas 17, 18, and 19) of the adult cat that respond in a precise and highly tuned fashion to external patterns – in particular bars or edges of given orientation and moving in a given direction. Much further work has been taken to indicate that the number and response characteristics of such cortical cells can be

modified.[12, 13, 14, 15] It has been observed, in particular, that the relative number of cortical cells that are highly specific in their response to visual patterns varies in a very striking way with the visual experience of the animal during the critical period.[16, 17, 18, 19]

Most kittens first open their eyes at the end of the first week after birth. It is not easy to assess whether or not orientation-selective cells exist at that time in striate cortex: few cells are visually responsive and the response's main characteristics are generally "sluggishness" and "fatiguability." However, it is quite generally agreed that as soon as cortical cells are reliably visually stimulated (e.g., at 2 weeks), some are orientation selective, whatever the previous visual experience of the animal. [17, 18, 19, 20]

Orientation selectivity develops and extends to all visual cells in area 17 if the animal is reared, and behaves freely, in a normal visual environment (NR): complete "specification" and normal binocularity (about 80% of responsive cells) are reached at about 6 weeks of age.[19] However, if the animal is reared in total darkness from birth to the age of 6 weeks (DR), none or few orientation-selective cells are then recorded (from 0 to 15% depending on the authors and the classification criteria); however, the distribution of ocular dominance seems unaffected.[13, 16, 17, 18, 19, 21] In animals whose eyelids have been sutured at birth, and which are thus binocularly deprived of pattern vision (BD), a somewhat higher proportion (from 12 to 50% of the visually excitable cells) are still orientation-selective at 6 weeks (and even beyond 24 months of age) and the proportion of binocular cells is less than normal.[22, 23, 24, 25, 26]

Of all visual deprivation paradigms, putting one eye in a competitive advantage over the other has probably the most striking consequences. If monocular lid-suture (MD) is performed during a "critical" period (ranging from about 3 weeks to about 12 weeks), there is a rapid loss of binocularity to the profit of the open eye.[22, 27] At this stage, opening the closed eye and closing the experienced one may result in a complete reversal of ocular dominance.[23] A disruption of binocularity that does not favor one of the eyes may be obtained, for example, by provoking an artifical strabismus [28] or by an alternating monocular occlusion, which gives both eyes an equal amount of visual stimulation.[29] In what follows, we call this uncorrelated rearing (UR).

These results seem to us to provide direct evidence for the modifiability of the response of single cells in the cortex of a higher mammal according to its visual experience. Depending on whether or not patterned visual information is part of the animal's experience, the specificity of the response of cortical neurons varies widely. Specificity increases with normal patterned experience. Deprived of normal patterned information (dark-reared or lid-sutured at birth, for example) specificity decreases. Further, even a short exposure to patterned information after six weeks of dark-rearing can reverse the loss of specificity and produce an almost normal distribution of cells.

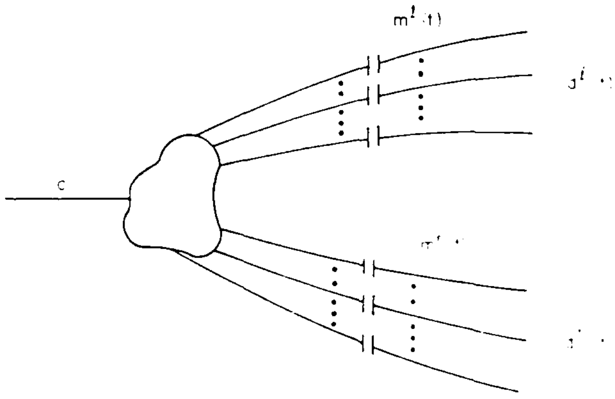
We do not claim and it is not necessary that all neurons in visual cortex be so modifiable. Nor is it necessary that modifiable neurons are especially important in producing the architecture of visual cortex. It is our hope that the general form of modifiability we require to construct distributed mappings manifests itself for at least some cells of visual cortex that are accessible to experiment. We thus make the conservative assumption that biological mechanisms, once established, will manifest themselves in more or less similar forms in different regions. If this is the case, modifiable individual neurons in visual cortex can provide evidence for such modification more generally.

Cortical neurons receive afferents from many sources. In visual cortex (layer 4, for example), the principle afferents are those from the lateral geniculate nucleus and from other cortical neurons. This leads to a complex network that we have analyzed in several stages.

In the first stage we consider a single neuron with inputs from both eyes (Figure 4).

Figure 4

A Model Neuron



Here d^l, d^r, m^l, m^r are inputs and synaptic junctions from left and right eyes. The output of this neuron (in the linear region) can be written:

$$c = m^l \cdot d^l + m^r \cdot d^r. \qquad (6)$$

This means that the neuron firing rate (in the linear region) is the sum of the inputs from the left eye multiplied by the appropriate left-eye synaptic weights plus the inputs from the right eye multiplied by the appropriate right-eye synaptic weights. Thus the neuron integrates signals from the left and right eyes.

According to the theory presented by Bienenstock, Cooper and Munro (1982, BCM)[30] these synaptic weights modify as a function of local and global variables. To illustrate we consider the synaptic weight.

Its change in time, $\dot{m}_i$, is given below:

$$\dot{m}_i = F(d_i \ldots m_i ; d_k \ldots c; \bar{c} \ldots ; X, Y, Z). \quad (7)$$

Here variables such as $d_i \ldots m_i$ are designated local. These represent information (such as the incoming signal, d_i, and the strength of the synaptic junction, m_i) available locally at the synaptic junction, m_i. Variables such as $d_k \ldots c$ are designated quasi-local. These represent information (such as the firing rate of the cell, or d_k, the incoming signal to another synaptic junction) that is not locally available to the junction m_i but is physically connected to the junction by the cell body itself—thus necessitating some form of internal communication between various parts of the cell and its synaptic junctions. Variables such as $\bar{c}$ (the time averaged output of the cell) are averaged local or quasi-local variables. Global variables are designated X, Y, Z . . . These latter represent information (e.g. presence or absence of neurotransmitters such as norepinephrine or the average activity of large numbers of cortical cells) that is present in a similar fashion for all or a large number of cortical neurons (distinguished from local or quasi-local variables presumably carrying detailed information that varies from synapse to synapse).

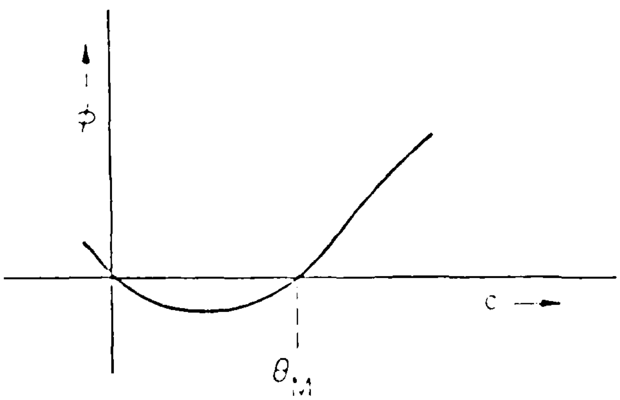
In a form relevant to this discussion, BCM modification can be written:

$$\dot{m}_i = \phi(c, \bar{c}; X, Y, Z \ldots) d_i \quad (8)$$

so that the j^{th} synaptic junction, m_i, changes its value in time as a function of quasi-local and time-averaged quasi-local variables, c and $\bar{c}$, as well as global variables X, Y, Z, through the function, ϕ, and a function of the local variable d_i. The crucial function, ϕ, is shown in Figure 5.

Figure 5

The BCM Modification Function



What is of particular significance is the change of sign of ϕ at the modification threshold, Θ_M, and the non-linear variation of Θ_M with the average output of the cell $\bar{c}$. In a simple situation:

$$\Theta_M = (\bar{c})^2. \quad (9)$$

The occurrence of negative and positive regions for ϕ drives the cell to selectivity in a 'normal' environment. This is so because the response of the cell is diminished to those patterns for which the output, c, is below threshold (ϕ negative) while the response is enhanced to those patterns for which the output, c, is above threshold (ϕ positive). The non-linear variation of the threshold with the average output of the cell, $\bar{c}$, places the threshold so that it eventually separates one pattern from all of the rest. Further it provides the stability properties of the system.

A detailed analysis of the consequences of this form of modification is given in BCM. The results (as modified in the network analysis outlined next) are in general agreement with what we might call classical experiments of the last generation. Neurons in normal (patterned) environments become selective and binocular. In various deprived environments (e.g. monocular or binocular deprivation) the theoretical behavior follows the experimental results.

To better confront these ideas with experiment the single neuron discussed above must be placed in a network with anatomical and physiological features of the region of interest. For visual cortex this suggests a network in which inhibitory and excitatory cells receive input from the lateral geniculate nucleus (LGN) and from each other. A simplified form of such a network, a first-order representation of the anatomy and physiology of layer IV of cat visual cortex (Figure 6) has been studied by Scofield and Cooper.[31]

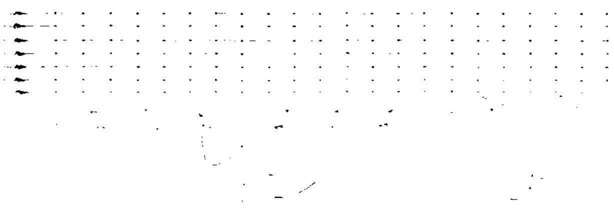
In a network generalization of Eq. (6), we write:

$$c_i = m_i^l \cdot d^l + m_i^r \cdot d^r + \sum_j L_{ij} c_j, \quad (10)$$

where L_{ij} are the intracortical connections.

Figure 6

A simplified Neural Network



Analysis by Scofield and Cooper of the network along lines similar to that of the single cell analysis described above shows that under proper conditions on the intracortical synapses, the cells converge to states of maximum selectivity with respect to the environment formed by the geniculate signals. Their conclusions are therefore similar to those of BCM with explicit further statements concerning the independent effects of excitatory and inhibitory neurons on selectivity and ocular dominance. For example, shutting off inhibitory cells lessens selectivity and alters ocular dominance. The inhibitory cells may be selective but there is no theoretical necessity that they be so.

A mean field approximation to the above network shows that if the average effect of intracortical connections results in inhibition of individual cells, then in monocular deprivation, the geniculocortical synapses to the cell will converge to non-zero states that give, as the result of stimulation of the closed eye, total responses that are zero.[32] However, the fact that the geniculocortical states are non-zero means that the removal of cortical inhibition through the chemical blocking of inhibitory synapses would uncover responses from previously non-responsive cells. This result is in accord with the experimental observation of 'masked synapses' after the removal of the inhibitory effects of GABA with the blocking agent bicuculline.[33, 34]

An unexpected consequence of this theory is a connection between selectivity and ocular dominance. The analysis given in BCM and extended in the mean field network theory shows that in monocular deprivation, non-preferred inputs presented to the open eye are a necessary part of the suppression of deprived eye responses. It follows that the more selective the cell is to the open eye (increasing the probability of non-preferred inputs) the more the closed eye will be driven to zero, thus increasing the dominance of the open eye (Figure 7a).

For an experimental test of these ideas it is important to determine what happens *during* the ocular dominance shift produced by monocular deprivation. An experiment in which monocular experience follows a period of dark rearing has been performed by Saul and Daniels (1986). Their results confirm the expected correlation between ocular dominance and selectivity (Figure 7b).

Figure 7

Progression of development of Selectivity and Ocular Dominance.

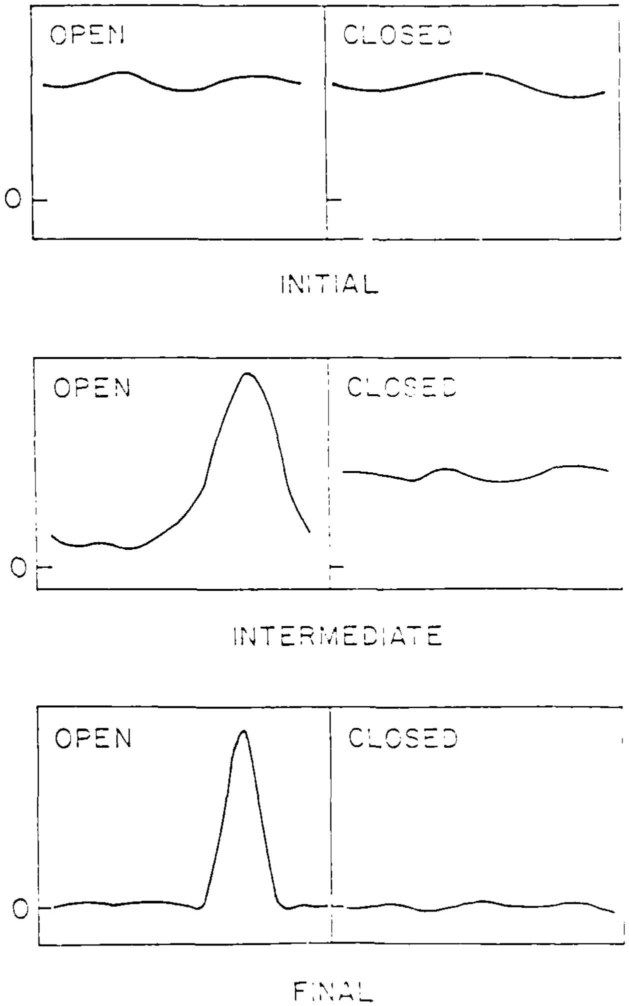
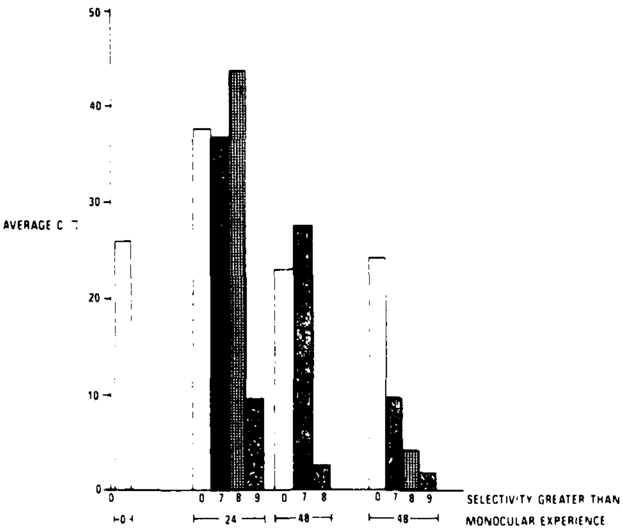


Figure 7b

Average left eye $\overline{c^2}$ versus right eye Selectivity and Monocular Experience.



One of the consequences of the network theory discussed above is that experimental results that have been obtained in visual cortex over the last generation can be explained primarily by modification of lateral geniculate (LGN) to cortex synapses with minimum changes among intra-cortical synapses. Thus the possibility is opened that most learning takes place in the LGN synapses. This somewhat surprising result has as one consequence the possibility of great simplification in the analysis of network modification.

An alternate hypothesis that has been considered for some time is that intracortical synapses bear heavy responsibility for modification in cortical circuitry during learning. (See, for example, Rauschecker and Singer, reference[35]). In particular, it has been suggested that ocular dominance shifts in monocular deprivation are due to increased activity of GABAergic neurons, the open eye supressing the closed. Sillito documented in normal cats that visually unresponsive cells may be "unmasked" by iontophoretic bicuculline.[36] Thus, it is not unreasonable to speculate that many of the unresponsive cells in visually deprived kittens are being suppressed. Together, these data suggest as a possible hypothesis that in kitten striate cortex the GABAergic neurons respond to sensory deprivation by forming new synapses. This hypothesis implies that the density or strength of GABAergic synapses will increase in zones of cortex that are deprived of a normal thalamic input; in the case of monocular deprivation, these zones correspond to the closed-eye ocular dominance columns and to the monocular segment contralateral to the deprived eye. On the other hand, the theory described above suggests that there will be minimal response of GABAergic neurons to sensory deprivation. This hypothesis has been put to test in a recent series of experiments.[37]

To examine the distribution of GABAergic synapses, Bear et. al. immunocytochemically localized GAD in sections of striate cortex.[37] While immunocytochemistry is not a quantitative measure, they reasoned that changes restricted to deprived ocular dominance zones should be readily detected with this method. As a quantitative estimate of GABAergic synapse density, they biochemically measured GAD activity in homogenates of striate cortex.

They found no evidence for a change in the distribution of GAD-positive puncta in 12 unilaterally enucleated kittens. The band of layer IV puncta remained uniform even though the periods of monocular deprivation examined would all be sufficient to cause a physiological ocular dominance shift in striate cortex. GAD immunoreactivity was unchanged even under conditions that produced alterations in the level of the metabolic enzyme, cytochrome oxidase. Measurements of GAD activity showed no consistent or significant difference between either the binocular segments of enucleated and control kittens, or the monocular segments of enucleated animals.

This conclusion is in striking agreement with network analysis which, as mentioned above, suggests that inhibitory synapses are much less modified by experience than excitatory synapses. In addition to its implications for the 'site of learning' such a hypothesis leads to important simplifications in the analysis of complex networks.

One of the most exciting of present projects is that of trying to find a molecular basis for synaptic modification. A molecular model for the BCM form of modification based on NMDA receptors has been proposed. In this model the BCM modification threshold is identified with the voltage-dependent unblocking of the NMDA receptor channels. A consequence of this identification is the requirement that the voltage dependence must vary depending on the history of the cell activity.

Stated in this language many questions become of obvious interest. Among these: How long does it take to adjust to a new average firing rate? What does the molecular model say about the interaction of various neural transmitters? Can we connect those cells that modify with those acted on by modulators? (e.g., if inhibitory cells modify less, perhaps they are less acted on by modulators?) Do the same rules apply in the developmental period as apply to reorganization in adults?

You have been sufficiently warned about the hazards of making predictions; now I will venture to say a few words about the future. Imagine first that the problem of how the brain functions and organizes information has been solved. What would the consequences be? There would clearly be medical applications, possible means for treatment and amelioration of various physiological and psychological disorders. Also there would be new means for information processing – organization of computers. We could very likely duplicate electronically the information processing functions so that we would have available to us, machines that would share our ability to learn and that could duplicate our processes of reasoning. Such devices would become standard components of what we today call computers.

I would guess that this would occur board by board – a gradual encroachment of intelligent components into conventional machines – somewhat like neo-cortex came to dominate the brain. The Aegis Combat System of the future will be dominated by such machines.

But will this problem be solved in our lifetime? When I began to work in this field about a decade ago, opinions were: an interesting problem but insoluble in our lifetime. Today, fashion has changed. Everyone talks about parallel processing, connection machines, and neural networks. What was heresy and put one in danger of being burned ten years ago has become received religion; but it is not sufficient to change religion. It is the details that count.

The object is to construct systems that can learn, that can modify their behavior depending upon their environment – and thus are to some extent self-organizing. But the details of the architecture that make these systems function effectively is not self-organizing – that is what we must construct. It's not sufficient just to build hardware, connect elements and see what happens with no real understanding of what might be accomplished. I hope that the current burst of enthusiasm for this field will not slacken if results do not come quite as quickly as sometimes promised.

And now that you are holding firmly to your wallets, I will predict that just as the 20th century is famous for its automobiles, airplanes and computers, the 21st century will be the century of intelligent machines. They will be produced initially as electronic duplications of models we will develop of how the brain functions and will no doubt progress rapidly beyond that. Such systems will become the inevitable accompanyment of what we today call computers and will eventually dominate these machines. They will become as ubiquitous as computers – in homes, offices, airplanes, and naval ships.

In addition, I confidentially predict that the Office of Naval Research will be in the forefront of these developments – both for contributions to the Navy of the future as well as to continue its proud record of investment in scientific research.

Biography

See Profiles in Science on page 14.

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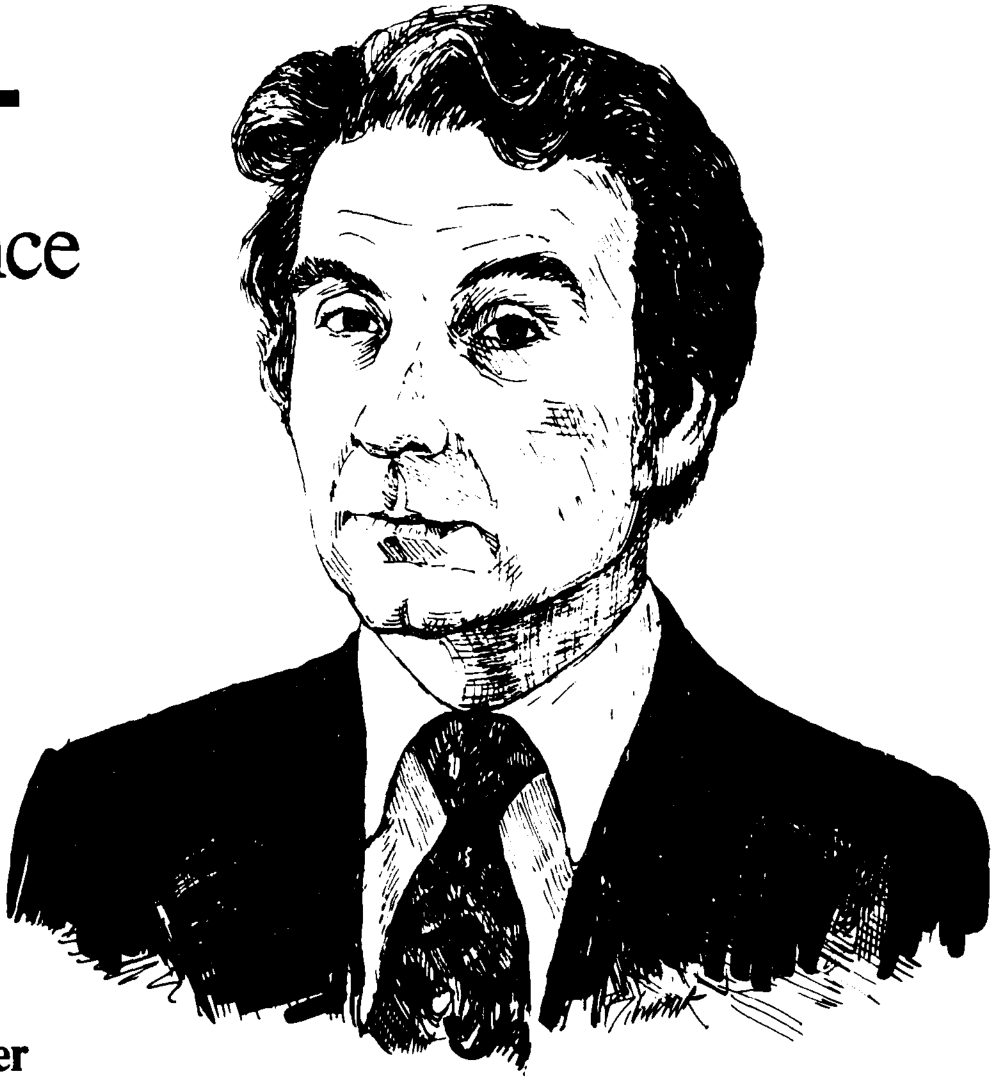
Profiles in Science



Leon N. Cooper

Dr. Leon N. Cooper is the Thomas J. Watson, Sr., Professor of Science and the co-director of the Center for Neural Science at Brown University where he has been on the faculty since 1958. For many years, he has been overseeing, as principal investigator, programs funded by the Office of Naval Research, beginning in the 1950's with research in the field of superconductivity to his current work in the realm of the central nervous system. In this issue on page 3, the article by Professor Cooper, "Future of Brain and Information Research," describes some of his recent research.

Cooper worked with J. Bardeen and J. R. Schrieffer to develop a microscopic theory of superconductivity, which they put forth in 1957. For this work, the three were awarded the Nobel Prize in physics in 1972.

In 1955, Bardeen invited Cooper, whose earlier training and experience had been in field theory and nuclear physics, to join him and Schrieffer in working out a theory of superconductivity. Cooper studied the behavior of a many-electron system interacting. For technical reasons, he focused his attention on two electrons at a time. Cooper showed that even for an extremely weak interaction, the energy spectrum of such a pair includes a bound state. In the presence of an attractive interaction, electrons near the Fermi surface could therefore form bound pairs (now known as Cooper pairs).

Bardeen, Cooper, and Schrieffer next constructed a wave function involving the cooperative motion of large numbers of particles, in which the Cooper pairs could freely scatter while obeying the exclusion principle. From this work developed the Bardeen-Cooper-Schrieffer (BCS) theory, which explained successfully all the remarkable properties of superconductors and also stimulated extensive theoretical and experimental research in superconductivity.

In recent years, in addition to his work in theoretical physics, Cooper is actively working in developing a theory of the central nervous system function. His particular interest is the means by which neuron modification can lead to the organization of distributed memories and the means by which central nervous system theory can be confronted by experiments on the visual cortex.

Professor Cooper is a member of the National Academy of Sciences, a Fellow of the American Physical Society, and a Fellow of the American Academy of Arts and Sciences.

Winter MIZEX 87: Operations Overview*

by Dean A. Horn,
Office of Naval Research

MIZEX (Marginal Ice Zone Experiment), a multinational, interdisciplinary study of the Arctic environment, has the overall goal to better understand the mesoscale interaction of ice, ocean, and atmosphere at the polar margin. Winter MIZEX is the natural extension of the successful 1983-84 Summer programs and this paper presents an overview of the MIZEX 87 operations, March 19 to April 13, 1987.

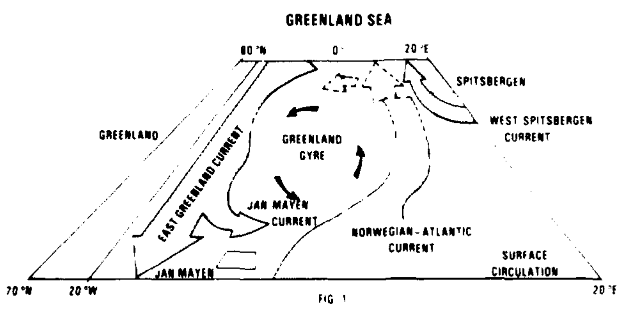
Principal scientific areas studied were: oceanography, meteorology, remote sensing, ice and waves, acoustics, and biology. Operations benefitted greatly from SAR imagery, downlinked daily, in near real-time, directly from SAR aircraft to POLAR CIRCLE. Preliminary reviews of just part of all the data acquired during MIZEX 87, indicate that knowledge of the Arctic environment will expand significantly when all the data are evaluated.

Introduction

Marginal Ice Zones (MIZ) exist where polar and temperate ocean zones meet and an ice-edge exists as a permanent, highly variable, geophysical boundary. A boundary, unique due to the complex vertical and horizontal air-sea-ice interactions that occur in the MIZ, it moves as much as 600 km north and south during each annual cycle. Improved modeling and better prediction of ice-edge position, ice concentration and ice type would be a major step in expanding man's activities in this frontier region; activities such as mineral exploration and development, seaborne commerce, better fishing, environmental monitoring and naval operations. Further, if mesoscale physical processes in the MIZ are more accurately parameterized for inclusion in the large scale models, the result will be a major aid in improving hemispherical climatological studies. Therefore, the overall objective of MIZEX is to gain a better understanding of the mesoscale physical and biological processes by which ice, ocean and atmosphere interact in the area of the ice edge[1, 2]. The Fram Strait region, between Svalbard and Greenland, was chosen for MIZEX East (Figure 1) because most of the heat and water exchange between the Arctic Ocean and the rest of the world is through this strait.

Figure 1

MIZEX East Research Area.



Summer experiments began with MIZEX 83, a limited scale operation, in June 1983. MIZEX 84, the full-scale summer experiment in May-July, is the largest coordinated, international Arctic research program yet conducted in the MIZ. A comprehensive report of the principal scientific results achieved by MIZEX 83 and 84 was prepared by the MIZEX Group and published in *EOS*, June 1986[3]. MIZEX data, research reports and journal articles are being filed in the National Snow and Ice Data Center (NSIDC), Boulder, Colorado (telephone: 303-492-5171). The MIZEX holdings index, available from NSIDC, is also posted and updated quarterly on the OMNET Telemail MIZEX Bulletin Board.

*Paper presented at Oceans 87 Conference and Exposition, September 1987, Halifax, Nova Scotia, Canada, sponsored by the Marine Technology Society and the Institute of Electrical and Electronics Engineers.

Objectives and Strategy

Fram Strait Winter MIZEX was based on the need, demonstrated by Summer MIZEX operations, to understand the ocean-atmospheric-ice processes responsible for the advance of the winter ice edge, and the effects on acoustics and electromagnetic remote sensing, under dramatically different conditions than in summer. Atmospheric interactions, ice growth, and surface gravity waves are most intense from about December to April. Annually, the upper ocean reaches its fully developed winter state about March. For this reason and for logistic and daylight considerations, MIZEX 87 was conducted mid-March to mid-April. Primary goals (2) of MIZEX 87 were to:

- ☐ Exercise and verify the remote-sensing capabilities for real-time detection and tracking of winter ice-ocean eddies;
- ☐ Provide the first comprehensive data set on the oceanography of the winter MIZ vital for ocean and acoustic modeling,
- ☐ Provide the first data on important meteorological questions and surface atmospheric boundary conditions in the Winter MIZ;
- ☐ Provide a unique data set on ice and surface gravity wave interactions in winter;
- ☐ Provide ambient noise data; and
- ☐ Obtain a unique data set on biological activity of the winter MIZ and with the onset of light.

Field Program

Description of the Experiment

The Fram Strait operating area for Winter MIZEX 87 (Figure 2) extended along the ice-edge from about 75°N to 79°N and 5°W to 5°E. This was augmented by coordinated deep oceanographic sections across Fram Strait from the Svalbard shelf to about 0°E and ending with a two day investigation of the Barents Sea MIZ between the south tip of Svalbard and Bear Island. The NOAA 9 satellite image of the Fram Strait area for 28 March (Figure 3), shows typical ice and weather conditions experienced generally throughout the MIZEX 87 operation.

Figure 2

MIZEX 87 Operations Overview

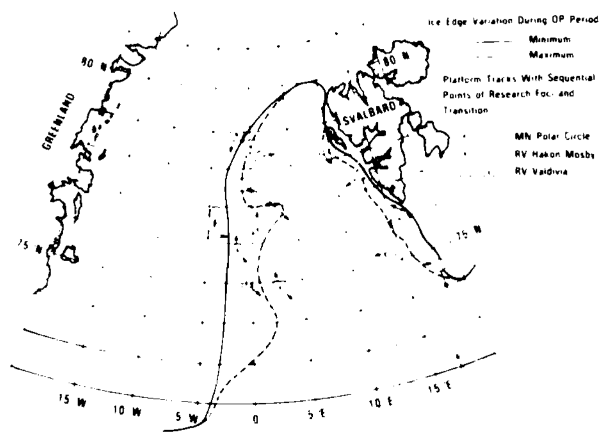


Figure 3

NOAA 9 March 28 image. MIZEX 87 OP area

Winter MIZEX 87 Operations (Figure 4), conducted between March 19 and April 13, consisted of three research ships, one helicopter, three fixed-wing aircraft and 62 scientists and technicians from Canada, German Federal Republic, Norway, United Kingdom and the United States. MV POLAR CIRCLE, a chartered ice-strengthened motor ship provided the required ice breaking capability and support helicopter for in-ice research covering oceanography, eddy studies, remote sensing, meteorology, ice physics, ice dynamics, meteorology and acoustics. RV HAAKON MOSBY, University of Bergen's open water research vessel, carried out coordinated programs in oceanography, eddy studies, biology and meteorology complementary to the in-ice projects onboard POLAR CIRCLE. RV VALDIVIA, University of Hamburg's open water research vessel carried out programs of large scale, deep water oceanography, biology and meteorology. Three fixed-wing aircraft supported the surface projects with a total of 31 overflights. STAR 1 or 2 (Intera, Calgary, Canada) carried Synthetic Aperture Radar (SAR) with direct, real-time downlink to POLAR CIRCLE. The STARs flew one or two missions every day from 28 March to 10 April. A NRL P-3, carrying Passive Microwave Imager (PMI), meteorological and photographic instrumentation, flew six missions providing extensive, concurrent coverage with the SAR studies. A RNAF P-3 flew three missions supporting oceanographic and acoustic studies in both the Fram Strait and Barents Sea.

The MIZEX 87 Field Organization (Figure 5) was under the overall coordination of O.M. Johannessen, Director, Nansen Center, University of Bergen, who was also Chief Scientist on POLAR CIRCLE. Field coordinator for aircraft was R.A. Shuchman, Environmental Research Institute of Michigan (ERIM), also onboard POLAR CIRCLE. Chief Scientist on HAAKON MOSBY was Johnny A. Johannessen, Senior Scientist, Nansen Center, Bergen; and on VALDIVIA, Detlef Quadfasel, IFM, University of Hamburg. To assist field operations, two shorebased coordination support centers were established; one in Tromso at the Norwegian Satellite Telemetry Station under D.A. Horn, MIZEX Executive Officer, and one in Longyearbyen, Svalbard under B. Burns, ERIM. The function of these support centers was to provide daily communications, ice movement reports, weather forecasts, ice-edge forecasts, aircraft flight plans, ARGOS buoy positions, and general logistic support.

For MIZEX 87, telefax via satellite telephone, ship to shore and landline, was the most effective and reliable means to communicate and relay data, especially charts or sketches, e.g. flight plans, ice edge charts, and weather patterns for the OP Area. Logistic support for MIZEX 87 was efficiently coordinated by A. Heiberg, Polar Science Center (PSC), University of Washington, with all scientific and support equipment successfully routed in and out of Bergen and Tromso, as required.

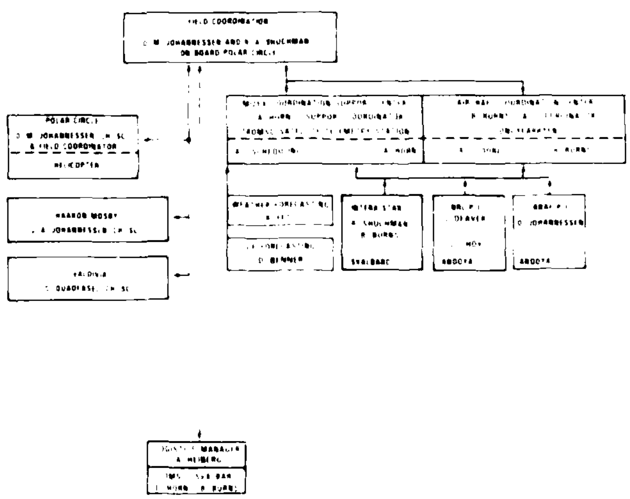
Figure 4

MIZEX 87 Field Operations

SHIPS			
MV POLAR CIRCLE	ICE STRENGTHENED	PSC U WASH	MARCH 20 APRIL 13
RV HAAKON MOSBY	OPEN WATER	U BERGEN	MARCH 18 APRIL 12
RV VALDIVIA	OPEN WATER	U HAMBURG	MARCH 12 APRIL
AIRCRAFT			
STAR 1 and 2	SAR	CANADA	MARCH 28 APRIL 10
NRL P 3	PMI MET	USA	MARCH 28 APRIL 8
RNAF P 3	AXBT SONABUOY	NORWAY	APRIL 3 APRIL 10
CONCURRENT FLIGHTS			
STAR 1 or 2	AND NRL P 3	MARCH 30 31	APRIL 3 7 8
STAR 2	AND RNAF P 3	APRIL 1 10	
STAR 2	NRL P 3 RNAF P 3	APRIL 2	
MIZEX PERSONNEL FROM 5 NATIONS:			
SHIPS 49	AIRCRAFT 7	SHORE SUPPORT 6	TOTAL 62

Figure 5

MIZEX 87 Field Organization



Principal Operations

Ship positions, with sequential points of research foci and transition (Figure 2), summarize MIZEX 87 activities. POLAR CIRCLE (circled letters) arrived at the ice-edge on 25 March (A) and began a mesoscale study of the MIZ in conjunction with HAAKON MOSBY (lettered boxes). Both ships proceeded northward along the ice edge to about 79 °N, arriving on 27 March (B). A large eddy field, consisting of a vortex pair, one cyclonic and one anti-cyclonic, was found and fully documented by oceanographic data obtained by the ships and by SAR imagery. On [illegible] March, POLAR CIRCLE (B) moored to an ice floe, deployed all ARGOS buoys and began a remote sensing, ice characterization drift period to 4 April (C). A second eddy field was found and again fully documented oceanographically and with intensive SAR studies of both the ocean and ice features. This study terminated on 8 April (D) and POLAR CIRCLE proceeded to the Barents Sea MIZ (E) for a two day, surface and remote sensing investigation of the area. Meantime, HAAKON MOSBY continued studies of the MIZ (C,D), thoroughly investigating off-ice oceanographic, meteorological and biological features of the area. HAAKON MOSBY departed the OP Area on 9 April and returned to Tromso with POLAR CIRCLE on 12 April.

R/V VALDIVIA (numbered triangles) started her first oceanographic transect off the coast of Norway on 17 March and proceeded northward past Bear Island to the south tip of Svalbard (2). Then operating with MIZEX, VALDIVIA made the first of three deep ocean transects across the Fram Strait (3-4, 5-6, and 7-8). At the end of the third transect, a three day, intensive Coastal Oceans Dynamics Radar (CODAR) study was carried out. Throughout the cruise, VALDIVIA conducted continuous meteorological studies and biological investigations consistent with the oceanographic program. VALDIVIA called Tromso on 4 April to off-load MIZEX personnel, then sailed for Hamburg the same day.

Operating Conditions

Operating conditions throughout the experiment were very favorable. Heavy weather occurred along the 75 °N parallel several times during MIZEX operations with 50 knot winds and 35 foot seas on at least two occasions: first, during POLAR CIRCLE and HAAKON MOSBY's March 22-23 transit, and second, during VALDIVIA's third transect (7-8). While wind intensity and direction in the OP Area varied widely, much to the satisfaction of the meteorologists, slow moving high pressure centers over North Greenland, kept the MIZEX OP Area relatively clear.

For MIZEX 87, helicopter operations were scheduled very conservatively with safety foremost because, having only one helo, there was no immediate air rescue capability and lacking previous experience, icing and weather were critical unknowns. Maybe by chance (but experienced Arctic fliers maintain March - April is a good operating period), the favorable weather during 87 MIZEX permitted a high rate of helo flying with only one operating day curtailed due to icing. Likewise, fog was not a problem. During these field operations, helo flying averaged three plus hours/day, slightly more than was flown during MIZEX 83 or 84, and this unexpectedly high usage rate was of great benefit to all projects.

Similarly, weather in Northern Norway grounded the NRL P-3, due to snow, only once. In Svalbard, the STAR aircraft were able to fly everyday. Most fortunately, ship and helo icing were not the problems that they had been expected to be.

The unanimous opinion of the Field Coordinator, the platform Chief Scientists and all participants was that Winter MIZEX attained all planned objectives because favorable weather and sea conditions permitted operating every day. Every project acquired important data, more than had been expected for this first Winter MIZEX.

SAR Remote Sensing

MIZEX 87 was the first international MIZ experiment having daily SAR coverage with direct downlink to the ships in the field (Figure 6). The SAR system, with its high resolution, clarity of image and virtual real-time availability, proved to be the most important and effective operational tool for planning and executing MIZEX 87 field investigations.

The power and capability of SAR as a scientific instrument were equally well demonstrated by the enormous volume of data recorded. Effectively imaging every piece of ice, there are hundreds of millions of tracers in every record. Thus, SAR will enable researchers to map out flow fields and to make detailed streamline studies of the MIZ. These data will require thorough and careful study to discover and fully assess the important knowledge acquired during MIZEX 87. Very preliminary, field assessment of a portion of the data already shows that:

- ☐ SAR can delineate multi-year ice, first year ice and many stages of young ice.
- ☐ SAR can detect the surface expression of eddy fields both in the open ocean and the ice pack.
- ☐ SAR, detecting ocean waves, can follow them about 100 km into the ice pack. SAR wave observations were confirmed by wave riders, pitch and roll buoys, and ice floe accelerometers.
- ☐ SAR imagery shows internal wave features in the open ocean and under the ice pack which were documented by in situ investigations.
- ☐ SAR data mapped an ocean polar front in the Barents Sea. This front was documented by POLAR CIRCLE and HAAKON MOSBY including meteorological instability studies across the front

Figure 6

Synthetic Aperture Radar (SAR) imagery of sea ice in the Barents Sea off the coast of Svalbard. (Image courtesy of the Environmental Research Institute of Michigan)

Oceanography

The mesoscale oceanographic studies of the MIZ along the ice-edge conducted by POLAR CIRCLE and HAAKON MOSBY will provide crucial data for comparative studies of the winter and summer environment. Perhaps of most significant are two intensive eddy investigations which found that eddies exist in vortex pairs, one cyclonic and one anticyclonic. First interpretation is that these eddies are topographically generated. The vortex pairs were documented using current temperature density (CTD) measurement device, drifting ARGOS buoys and current meters. During MIZEX 83 and 84, observations only dealt with the cyclonic portion due to the quick ice melting in an anticyclonic eddy. It is expected that MIZEX 87 eddy studies will produce important, new information about shelf dynamics.

Extensive, off-ice oceanographic studies by HAAKON MOSBY discovered an interesting, chimney-like, feature. This chimney contained the warmest, most saline water yet found in an eddy structure. Water under the pancake ice, at depths of 150-200 m, was over 3° C, while the shallow surface layer was as cold as −1.9° C. Salinity of the warm water was near 35 parts/thousand. CTD stations in the area, but not directly in the chimney, showed a very weak thermocline in the chimney; a strong indication of the initiation of convection, according to Chief Scientist J. A. Johannessen (4). The area was extensively mapped using SeaSoar and detailed data analysis must be made to fully evaluate this finding.

Oceanographers on VALDIVIA reported an excellent cruise, with only one station affected by foul weather. Due to the ice-edge location, VALDIVIA revisited every oceanographic station made during Summer MIZEX 84. Researchers have thus acquired a complete data comparison for summer and winter conditions. Detailed study of the data is required before the full significance of results are known.

Meteorology

Meteorological studies were conducted throughout the field operations. Multiple, coordinated rawindsonde launches were made by each ship, four to six times every day. Ship mounted instrumentation and SODAR on HAAKON MOSBY produced an extensive set of near surface data. These data will be augmented by high altitude data acquired by instrumentation onboard NRL P-3. Initial indications from all data are that an unstable boundary layer condition existed off the ice-edge during the MIZEX 87 operations.

Ice

Ice and snow properties were sampled at forty locations on 32 individual floes in the Fram Strait and Barents Sea. Ice sampling, by coring each location, provided core measurements of temperature, salinity, density and ice structure. Brine and air volumes will be calculated from these values. Thick core section samples were prepared and returned to Cold Regions Research Engineering Laboratory (CRREL), Hanover, New Hampshire, where detailed structural, optical and bubble distribution measurements will be made. Snow properties, measured in snow pits at many sites, include depth, evidence of layering, density, grain size and grain shape. In situ optical properties of the ice were measured at many locations: incident and reflected radiation just above the ice and snow surface; transmitted light just beneath the ice. The measurements were made at five frequencies. Ice and snow properties, determined in conjunction with active and passive microwave measurements, were coordinated with other researchers on POLAR CIRCLE. These data will also provide ground truth for airborne SAR and passive microwave instrument (PMI) data.

Acoustics

Ambient noise studies were carried out by an RNAF P-3 during three flights, two in the East Fram Strait, one in the Barents Sea. Large numbers of Sonabuoys, dropped in precise patterns by the RNAF P-3, were supplemented by helo deployments in the compact ice-edge regions. Simultaneous with these acoustic investigations, SAR, wave, meteorological and oceanographic variables were documented. These data will enable researchers to study the acoustic signals recorded by the RNAF P-3 to determine what geophysical processes are the principal generators of ambient noise in the Arctic MIZ.

Biology

In MIZEX 87, growth rates and the standing stock of phytoplankton, and reproduction and development of dominant zooplankton species were investigated prior to the spring phytoplankton bloom. This study of the reproductive state of, and strategy utilized by copepods preparing for the bloom period, appears to have been very successful. Work involved underway sampling of surface water for phytoplankton, nutrient and zooplankton biomass determinations. Sea surface water was continuously filtered through nitrex cups during oceanographic SeaSoar transects. Underway plankton samples were collected and preserved for observations of abundance and species composition. These data will be useful in conjunction with SeaSoar data to determine location and origin of fronts associated with eddies.

During biology transects across eddies, net hauls assessed abundance, taxonomy and development stages of zooplankton species present. Profiles of light, chlorophyl, pheophytin, nutrients and potential primary production in sections across eddies documented low phytoplankton growth rates in the deeply mixed upper layers. Seventy-five abundance samples were collected at various depths, surface to 1500 m. Net hauls were sorted and dominant copepods isolated for other measurements, including dry weight, for biomass estimates, lipid extractions, egg production and gut fullness experiments. Similarly, gut fluorescence measurements, indicating herbivorous feeding by copepods, show that the dominant species had very little food in their guts at all times. Low concentrations of chlorophyl at all locations and low rates of primary production verified the prebloom conditions existing in the study area.

Operational Conclusion

Winter MIZEX 87, a first in many aspects of Arctic MIZ research, was an operational success. All the MIZEX 87 OP Plan objectives were attained. The scientific successes, expected to make important contributions to man's knowledge and understanding of the Arctic, is just a first step, a pilot for the important future research programs now being planned. It is clear, the success of Winter MIZEX 87 has demonstrated the need and justified continuing Arctic winter research until the Arctic MIZ is thoroughly understood in all seasons and conditions.

Acknowledgements

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Biography

Dean A. Horn is Executive Officer of the MIZEX Program in the Office of Naval Research. His papers and research have been primarily in the field of Ocean engineering as well as research coordination and management.

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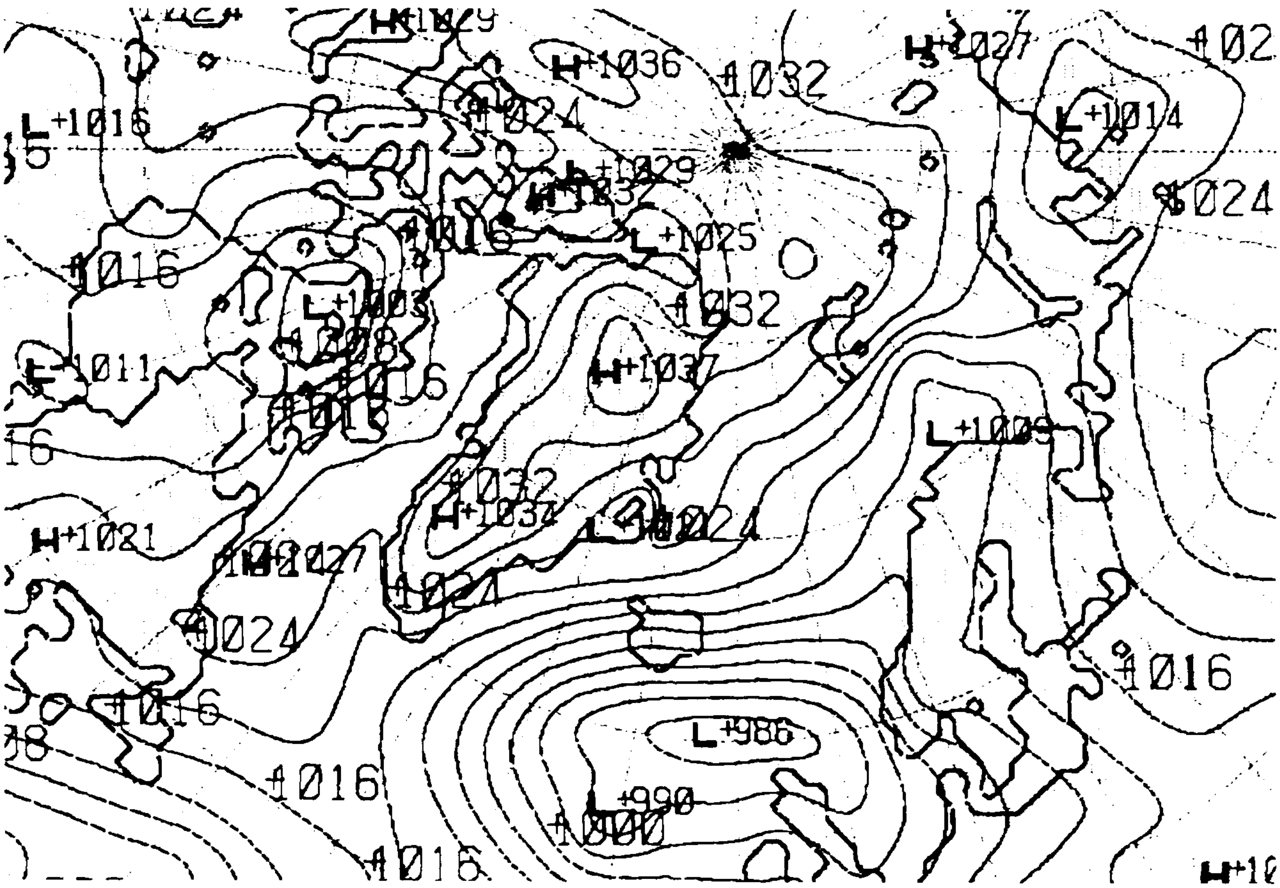
ATMOSPHERIC RESEARCH AT THE NAVAL ENVIRONMENTAL PREDICTION RESEARCH FACILITY

by LT Tim J. Dowding, USN,
Naval Environmental Prediction Research Facility



As one of the smallest field activities of the Chief of Naval Research, the Naval Environmental Prediction Research Facility (NEPRF) fulfills several unique missions within the realm of naval research. The mission statement of NEPRF is to: "Conduct research and development directed towards providing objective local, regional and global environmental analysis and prediction techniques; and to provide planning, modeling and evaluation services for determining the effects of environmental elements on naval weapon systems." NEPRF is the only Navy research facility solely dedicated to atmospheric research, and also the only one tasked by its mission statement to determine environmental effects on weapon systems.

The goals of the Facility are: to improve the quality of forecasting techniques and products available to the Fleet; to increase the Navy's knowledge of the environments in which it operates; to develop techniques for assessing the effects of atmospheric conditions on ship and air platforms and on shipboard, airborne and landbased naval communications, sensors and weapon systems; and to improve techniques for the processing, display and utilization of environmental satellite data in support of fleet operations.

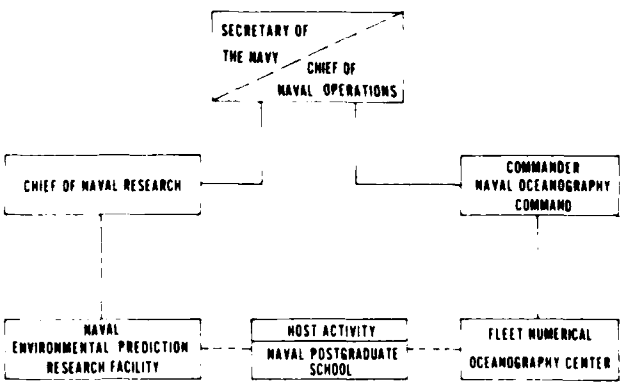
Many of NEPRF's research efforts transition to operational products utilized by naval forces, both afloat and ashore. Examples include the Navy Operational Global Regional Atmospheric Prediction System (NOGAPS NORAPS), numerical models used by the Fleet Numerical Oceanography Center (FNOC) for short and medium range weather prediction; the Geophysics Fleet Mission Program Library (GFMPL) which is used as a central site repository for command and control, and tactical decision aid computer software; the Tactical Environmental Support System (TESS(3)), a new major acquisition project being developed as an automated approach to the analysis and forecasting of environmental parameters in a ship-board environment; and the Navy Tactical Applications Guides which provide insight into the utilization of satellite data in various regions of the world.

History

In October 1950, the Bureau of Aeronautics established Project AROWA (Applied Research in Operational Weather Analysis) at the Naval Air Station, Norfolk, Virginia. This project was the weather research component of the Fleet Weather Center, Norfolk. It was redesignated the Weather Research Facility, Norfolk in October, 1957. The Environmental Prediction Research Facility (EPRF) was established in May, 1971, and moved from Norfolk to its present location in Monterey, California. In April 1972, Project FAMOS (Fleet Applications of Meteorological Observations from Satellites) was merged with EPRF, which was renamed the Naval Environmental Prediction Research Facility (NEPRF) in September, 1975. The most recent organizational change was the transfer of NEPRF from the Naval Air Systems Command to the Chief of Naval Research in May 1985 (see Figure 1).

Figure 1

Command Relationships



The Command

NEPRF is a tenant activity of the Naval Postgraduate School (NPS), and is located in four buildings at the NPS Annex. The Fleet Numerical Oceanography Center (FNOC), a major user of NEPRF products, is also at the Annex.

Among NEPRF's major equipment items are a readout antenna for stretched Geostationary Operational Environmental Satellite data; a Concurrent Model 3260 computer; Data General MV-4000 and ECLIPSE minicomputers; HP-9020, HP-9845, and Zenith 120 and 248 microcomputers and a Heurikon system. These systems, along with substantial time available on FNOC-owned Control Data Corportation CYBER 175, 855 and 860 main frames (including a CYBER 205 vector super-computer), are used for the development of faster and more accurate long and short range atmospheric forecasting algorithms tailored to Navy operational requirements. NEPRF operates a wide range of other facilities in support of its research mission including a satellite digital data laboratory, meteorological laboratory, electronic maintenance shop, photographic laboratory, and graphics shop, all of which are staffed by highly skilled Navy enlisted personnel. The Facility also maintains a Technical Library which serves the researchers' need for environmental literature such as technical reports, reference books, textbooks, programming documents and scientific journals in the fields of meteorology, atmospheric physics, air-sea interaction, and other related sciences and technologies.

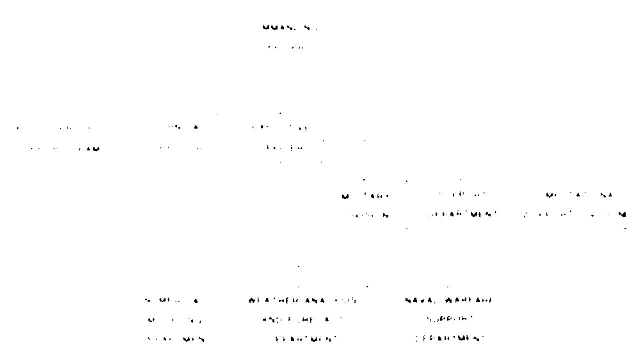
Personnel

The Commanding Officer of NEPRF is CDR Manuel G. Salinas, USN who is assisted by the Technical Director, Dr. John B. Hovermale, in supervising the R&D efforts of eleven military and 53 civilian personnel. Some unique features regarding personnel are that approximately half of the civilians have Master or Doctoral degrees, and that all six of the naval officers are in the Restricted Line, Special Duty Oceanography branch.

NEPRF has three research departments: Numerical Modeling, Weather Analysis and Forecast, and Naval Warfare Support. Their areas of geophysical research range from the air-sea interface through the earth's atmospheric boundary layer to the lower stratosphere. In addition, there is a Support Department, Computational Support Division, a TESS(3) Project Support Team, and an Integrated Satellite Data Base (ISDB) Project Support Team (see Figure 2).

Figure 2

NEPRF Organization



Program Work

NEPRF is a full service Research and Development facility, initiating programs in Exploratory Development (6.2) and seeing them through to Advanced (6.3), Engineering (6.4) and Support to Operational Systems (6.6), and finally into operational implementation. The Facility augments the work of its in-house staff with grants and contracts to a broad base of universities, private research establishments and other government laboratories.

The research performed by the various universities covers a wide variety of topics, yet is related to gaining a better understanding of the geophysical processes that occur in the planetary boundary layer (PBL). The University of Washington is currently conducting an analysis of satellite derived microwave water vapor measurements to determine air mass and frontal boundaries over the ocean. This analysis will provide an inferred correlation of satellite imagery with quantitative precipitation. Supportive work by Louisiana State University relates satellite imagery to inferred changes in the PBL by correlating high resolution airsonde measurements over ocean fronts and eddys with satellite photos that are colocated in space and time. This work describes changes in the PBL structure over the ocean in areas of thermal discontinuity.

Colorado State University is documenting the development of typhoons as observed by satellite imagery in various ocean basins. This work will eventually form the basis of a volume in the Navy Tactical Application Guide (NTAG) series. The Naval Postgraduate School provides a valuable pool of talent from both its faculty and thesis students. Satellite studies, arctic studies, air-sea interaction, Forward-Looking-Infrared-Radar (FLIR) analyses, and numerical modeling are just a few of the many geophysical research initiatives being pursued at NPS.

The Office of Naval Research (ONR) University Research Initiative (URI) is an ongoing 6.1 program which has a Congressionally approved research grant for the next five years for topics of interest to the Department of Defense. NEPRF's role in the URI program is to interact with the universities involved, and act in an advisory capacity with those universities conducting research directly related to ongoing work at NEPRF. As advisor, NEPRF assists in the transition of technology and knowledge from 6.1 Basic Research into the 6.2 and 6.3 research areas. Two URI participants are Pennsylvania State University and Scripps Institution of Oceanography, the University of California, San Diego. Penn State is conducting modeling studies and field experiments using ground based remote sensors to understand the evolution of the PBL. The sensors can reveal detailed vertical structure in the atmosphere. Scripps is conducting experiments in the atmosphere-ocean interface, using models to determine the dominant physical processes influencing mesoscale ocean variability. A joint experiment to be conducted between the two universities and NEPRF is planned for 1989. The purpose of the experiment is to measure a fully 3-dimensional PBL, which includes the atmosphere, ocean, and air-sea interface.

NEPRF also participates in a unique university program sponsored by the National Center for Atmospheric Research (NCAR). The purpose of the NCAR project is the improvement of global analysis modeling of tropical region moisture fields. New techniques and procedures in both software and diagnostics are being utilized to assess geophysical relationships in this global analysis.

Departments

The Facility's R&D is performed within its three departments, the technical activities of which are summarized below.

The **Numerical Modeling Department** develops, tests and implements numerical computer models of atmospheric analysis and prediction on scales ranging from the marine planetary boundary layer or air sea interaction phenomena, through regional phenomena (e.g., tropical cyclones, Mediterranean and/or China Sea weather), to global weather. The models are used primarily on the large main frame computers at FNOC.

The **Naval Warfare Support Department** develops, tests and implements command and control (C^2), and tactical decision aids (TDA) which support fleet operations. Additional NWS work furthers understanding of the effects of the environment on platforms and weapon systems.

The **Weather Analysis and Forecast Department** develops, tests and implements techniques, forecast aids and applications guides that define the impact of the environment on naval operations. This department also provides environmental information and guidance to tactical planners and commanders by such means as synoptic forecasting

guides on a regional scale; statistical techniques for weather analysis/forecasting; and studies of tropical phenomena to support operational forecasting. Other responsibilities include the development of decison aids and solving problems unique to the tropical latitudes. Additionally, the department is responsible for the development, testing and implementation of techniques for remote field and central site processing and display of environmental satellite data from imagers (IR, visible, microwave) and sounders. This sensed data can then be converted to geophysical parameters such as winds, sea surface temperatures, ice thickness and age, atmospheric temperatures, and moisture.

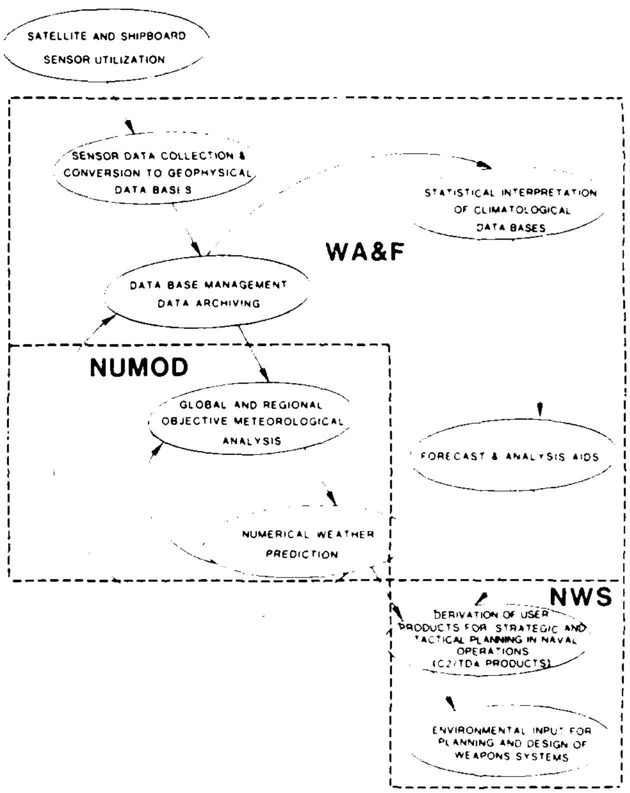
Research Thrusts

The broad scope of environmental prediction requires a multi-dimensional approach toward addressing R&D issues of relevance to the Navy. NEPRF's organizational strategy for resolving these challenges is similar to that used in the ancient problem of how to eat an elephant: one bite at a time. The goal of improved environmental prediction is partitioned into various subcategories between the three departments such that the resident expertise within each department is efficiently and effectively brought to bear on a particular task. Each task comprises an integral piece of the overall "big picture." In some subcategories, there is overlap between departmental responsiblities. This is not surprising since this relationship enhances the transitional progression of research between subcategories towards a final goal.

A typical flow of environmental information from data collection to end product is shown in Figure 3. It begins with the utilization of information from an array of environmental sensors, which is then converted from raw data into geophysical data bases. These data bases are quality controlled, archived and manipulated to provide a data base tailored to specific needs. One such use of data bases is for initialization of numerical weather prediction models such as NOGAPS/NORAPS that forecast atmospheric/boundary layer geophysical parameters. Another use is for producing statistically interpreted climatologies which may be used to develop synoptic and mesoscale weather analysis and forecasting rules. The climatologies may also be used to conduct sensitivity analyses of environmental effects upon weapon or sensor systems. By bringing together numerical models, climatologies, forecasting rules, and sensitivity analyses, tailored command and control (C^2) products and tactical decision aids (TDAs) can be derived for use by strategic and tactical planners. The next section will highlight some of NEPRF's recent work and how this work progresses between the aforementioned subcategories towards their final goals.

Figure 3

Flow of environmental information data processing



Recent Accomplishments

Data Collection and Conversion

A new program to predict visibility from satellite radiance data was developed. A data set, including surface aerosol, visibility and meteorological information, was collected in the western Mediterranean to verify the aerosol/visibility program.

Another newly initiated research effort is directed at investigating the use of surface based remote sensing to probe the marine atmospheric boundary layer (MABL). The data obtained will lead to a better understanding of the MABL, as well as reveal possible applications of the sensors themselves, which will lead to improved numerical models, TDAs, and instruments. A better understanding of the MABL will also result in improved predictions of environmental effects on weapon systems.

Data Base Management and Archiving

Previous work in satellite data applications has concentrated on the use of single sensors to retrieve environmental parameters. Research is now demonstrating that satellite data can be more fully exploited by combining data from two or more sensors to derive additional geophysical parameters which cannot be derived from a single sensor. An example of multisensor data manipulation is the use of multiple channels of the Advanced Very High Resolution Radiometer (AVHRR) to retrieve sea surface temperatures. This same concept of synergism is used in the analysis of atmospheric fronts using SEASAT Scatterometer (SASS) and Scanning Multichannel Microwave Radiometer (SMMR) data in combination to specify frontal location. Still another example is the computation of precipitation using microwave data from the NIMBUS SMMR and optical data from the AVHRR.

The Integrated Satellite Data Base (ISDB) will provide a means of colocating data from multiple channels, multiple sensors, and multiple satellites. Within the ISDB, a common structure for storing the data will preserve the measurement characteristics of the individual sensors, and concurrently make the data available in a common format to the researcher who is developing applications based on the concept of a "virtual" sensor. The structure of the ISDB is being designed with the realization that applications developed using the ISDB will eventually be transferred to an operational environment, either at FNOC or at local and regional sites on the TESS(3).

A North Pacific tropical cyclone climatology update was recently completed. This update includes all available data between 1945 and 1984 and provides information regarding the major storm tracks, frequency of cyclone occurrence, as well as constancy and average speed of storm movement. The results are documented in a NEPRF technical report.

The development of a new method to analyze meteorological observations of wind and temperature, which is an improvement on the Multivariate Optimum Interpolation (MVOI), was completed after a three-year development effort. The new analysis system was transitioned to the 6.3 Navy Operational Global Atmospheric Prediction System (NOGAPS) for advanced development and operational implementation. The MVOI provides a significant improvement over the current operational system, specifically in its ability to ingest new types of satellite data into atmospheric models. The new analysis produces improved initial conditions for numerical forecasting, thereby providing an important contribution to the goal of a skillful two-week forecast.

Numerical Analysis and Weather Prediction

The next-generation Navy Operational Global Atmospheric Prediction System (NOGAPS 3.1) has a new analysis-data assimilation system that makes optimum use of satellite data to define the initial conditions for the forecast model. The NOGAPS 3.1 spectral forecast model was tested with sophisticated diabatic processes including radiation, cumulus parameterization, and ground hydrology. Test runs of NOGAPS 3.1 were conducted with higher resolution using various data fields. This higher resolution achieves a significant improvement over the current NOGAPS and will provide the Navy with substantially better global analysis and forecast products. NOGAPS (3.1) is scheduled to become operational at the FNOC early in FY88, replacing the existing operational system (NOGAPS 2.0) that has run since 1981. NOGAPS 3.1 will also provide improved air-sea fluxes to drive ocean prediction models. The system is designed for eventual operation on the Large Scale Computers (LSC) being procured by both the Institute for Naval Oceanography (INO) and FNOC.

Another major accomplishment was achieved by successfully nesting a sophisticated higher order closure (HOC) planetary boundary layer (PBL) model in the Navy Operational Regional Atmospheric Prediction System (NORAPS). The development of the nested PBL model was in response to a request by FNOC to increase the emphasis on the PBL in the Navy's operational atmospheric prediction models. The higher order closure technology used will allow direct model prediction of PBL clouds, fog, and visibility. Since the model also predicts the turbulent properties of the PBL, direct prediction of radar refractive index profiles is possible, as well as the presence of surface-based and elevated radar ducts. Several real data forecasts in the North Atlantic were made which showed the HOC PBL model is able to accurately predict PBL changes. In addition to the maritime forecasts, several land area forecasts were run to assess the model's potential for predicting PBL conditions over land. Results so far are very promising and suggest that a next generation NORAPS using the HOC PBL will give the Navy substantially more information describing PBL conditions than is possible with current models.

A major accomplishment in regional modeling in 1986 was the development of the Advanced Tropical Cyclone Model (ATCM). Development of the ATCM culminates a series of enhancements to NORAPS. Three methods of incorporating tropical cyclone structure into the ATCM were devised. Limited testing of one of these methods yielded a 15% reduction in 48 and 72 hour forecast errors from those of the present operational model. A study by Brand and Blelloch in 1975 showed that a 20% improvement in the ability to forecast tropical cyclone tracks would net several million dollars in savings to DOD per year. One of the factors contributing to large tropical cyclone forecast errors is the interaction between multiple cyclones, a common occurrence in the western Pacific. The ATCM has been designed to allow for multiple storms in the forecast grid, which will allow storm interactions to occur during the model forecast. No other tropical cyclone forecast model in the world has this capability. Another ATCM feature is the improved simulation of moist processes, yielding more skillful modeling of typhoon structure and better storm track forecasts. Better methods of bogusing initial typhoon size and strength were

developed, making storm strength forecasts possible. Preliminary results of model performance on track forecasts indicate significant improvement over current operational typhoon forecast models. Parallel operational testing of the ATCM along with current operational models will be conducted this summer.

A 3-D numerical simulation which reproduced the physical mechanisms responsible for a satellite-observed calm zone in the middle of Monterey Bay, California was completed. Sensitivity testing isolated the conditions conducive to this anomalous effect. A second set of high-resolution, 3-D experiments was used to explore cloud-top entrainment instability. It is believed that entrainment instability is the mechanism which controls the breakup of maritime stratus into cumulus. This instability criterion is important because it represents the parameterization which controls subgrid stratus breakup in NOGAPS.

A correlation matrix program was developed for the Atmospheric Forecast Verification System (AFVS) to systematically display the forecast biases of NOGAPS. AFVS considers the entire life cycle of individual midlatitude storms and depicts the model biases of storm movement and growth on a simple grid mesh.

The Navy Over-Water Local Atmospheric Prediction System NOWLAPS is a one-dimensional, planetary boundary layer model being designed for TESS(3). NOWLAPS has been successfully implemented on the HP9845B desk top computer. A manual method for defining the horizontal advection tendency terms on board ship was designed using a stationary weather station ship to simulate an aircraft carrier. Forecasts were made and compared to comparable forecasts made by the Navy Operational Local Atmospheric Prediction System (NOLAPS), which is the central-site version of NOWLAPS.

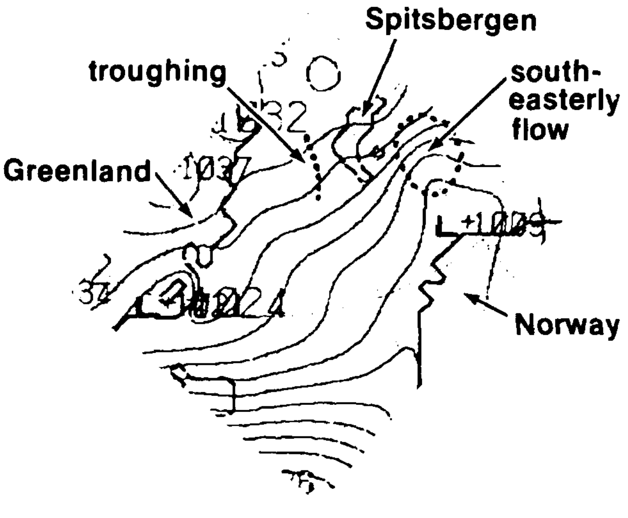
NEPRF examined and documented an episode of explosive cyclogenesis using satellite imagery in conjunction with the Arctic Marginal Ice-Zone Experiment (MIZEX). An evaluation was performed on a special series of numerical forecasts of the explosive episode using NORAPS. This study showed NORAPS' capability of forecasting significant cyclogenesis in the Arctic. NORAPS' forecasts of storm-force low level winds were verified against actual observations. NOGAPS completely missed both the location and intensity of this cyclogenesis, forecasting winds of only 15 knots. This documented study is the first in a series to be developed for inclusion in the Arctic volume of the Navy Tactical Applications Guide (NTAG) series with conclusions summarized in the forthcoming Arctic Forecaster's Handbook. An example of this study is shown in Figures 4 and 5.

Figure 4

A NOAA-10 High Resolution Picture Transmission (HRPT) infrared (IR) image from 25 March 1987 at 1750 GMT. The island of Spitsbergen appears in the upper right portion of the image with Greenland in the upper left. A wave-like phenomenon is revealed in the Fram Strait between Spitsbergen and Greenland. Easterly off-ice flow is revealed by cloud lines in the region southeast of Spitsbergen.

Figure 5

A Navy Operational Regional Atmospheric Prediction System (NORAPS) 48-hour forecast valid for 25 March 1987 at 1200 GMT. The forecast verifies the strong easterly flow revealed by cloud lines in the satellite data in the region southeast of Spitsbergen. The wave development in the Fram Strait is also suggested by the weak inverted trough shown near the west coast of Spitsbergen.



Statistical Interpretation of Climatological Data Bases

Software was developed to compute statistical structure and correlation functions of a satellite-derived, cloud motion wind field. This software objectively estimates the inherent random and instrumentation errors of satellite wind data without correlation with in-situ measurements.

The Combined Confidence Rating System (CCRS), built specifically to archive all official and objective aid forecasts for the convenience of the Joint Typhoon Warning Center (JTWC) forecasters, was brought to operational status. All tropical cyclone forecast data since 1978 were included in the CCRS data set. JTWC forecasters can now access CCRS data to perform routine post-storm error analysis on Zenith 120 micro-computers. An algorithm for the CCRS objective consensus forecast was developed. The weight of each aid contributing to the consensus forecast is computed according to the aid's past forecast accuracy.

A climatological study addressing environmental conditions during HARPOON cruise missile flight tests conducted at the Pacific Missile Test Center (PMTC) was completed and published as Weapons Environmental Sensitivity Report No. 8, "Environmental Conditions During HARPOON Missile Flight Tests Conducted at Pacific Missile Test Center."

Forecast and Analysis Aids

The Navy Tactical Applications Guide, Vol. 6, Part 1, "Tropical Weather Analysis and Forecast Applications" was completed as well as an initial draft of a "Forecaster's Handbook for Japan and Adjacent Seas".

Port studies were completed for Gaeta and Naples, Italy, and Ashdod and Haifa, Israel. These studies are designed to provide ship captains with the necessary guidance to avoid severe weather and sea states at selected ports in the Mediterranean. An update to a Hurricane Havens port study for Norfolk, Virginia, was also completed based on new data from the 1979 through 1985 hurricane seasons.

Command and Control/Tactical Decision Aid Products

Command and Control (C^2) oriented products for the Naval Environmental Display Station (NEDS) continued to gain increasing acceptance by Fleet users. The NEPRF-developed products were documented in a Fleet Numerical Oceanography Center Instruction as a Support Products Users Guide.

In conjunction with NPS, the first in a series of planned experiments was conducted to collect data to validate the newly upgraded Forward Looking Infrared (FLIR) performance model. The successful test marked the first time an effort was made to collect FLIR data and concurrent ground truth and target data.

A series of atmospheric propagation models (FASCOD, LOWTRAN and EOSAEL) developed at the Air Force Geophysics Laboratory and the Atmospheric Sciences Laboratory were acquired and installed on FNOC mainframes. These models form a nucleus of software for use in electro-optical transmission modeling and provide an additional basis for model validation in other efforts such as SKYLITE high energy laser (HEL), FLIR and millimeter wave model comparison and validation. FASCOD was used to analyze Light Detection and Ranging (LIDAR) tracking errors for a system installed at the Naval Air Test Center (NATC) last April. Soundings taken during experiments at NATC provided the environmental data from which errors due to atmospheric effects and refractive conditions were deduced. Atmospheric transmission models have been used extensively to investigate HEL transmission. A molecular absorption climatology for White Sands, NM was developed using one of the models. Molecular absorption estimates during real time HEL tests were also verified.

Platform and weapon system environmental sensitivities were analyzed for TOMAHAWK and HARPOON cruise missiles, and LAMPS helicopters. Additional TOMAHAWK Land Attack Missile (TLAM) test data were incorporated into the temperature sensitivity study begun in 1985 by Pacific Missile Test Center (PMTC) personnel. This additional data substantiates previous findings of an onboard temperature bias in TLAM. This temperature bias may negatively impact fuel usage and weapon system effectiveness.

A Light Airborne Multi-Purpose System (LAMPS) Environmental Support Packet and surveys were developed and distributed via the Commander, Naval Oceanography Command (CNOC) to COMSEABASWINGSLANT and COMASWINGPAC for further distribution to LAMPS MK I and MK III squadrons. The response by the LAMPS community showed a significant desire to improve environmental support for the diverse sensors and missions associated with this platform. This was summarized in a NEPRF Technical Report, "LAMPS Environmental Support Survey."

A report entitled "Remote Sensing of the Atmosphere in the Vicinity of the Battle Group" was completed. The purpose of the study was to identify state-of-the-art remote sensing instruments and techniques that could be adapted for shipboard use to satisfy battlegroup environmental data requirements for TESS(3). The following surface based remote sensing instruments were reviewed: LIDAR, RADAR, SODAR, microwave radiometers, UHF/VHF profilers and radiosondes. The advantages and disadvantages of each were determined and their applicability for afloat installation considered. The study concludes that a combination of lidar and radar will provide the best overall coverage. This combination will allow improved planning and operations by providing timely, high resolution data describing environmental parameters which affect battlegroup sensors and platforms. The recommendations developed under this effort will form the basis for further exploratory research into specific applications of systems such as the AN/SPY-1 radar for meeting meteorological data requirements within the battlegroup.

Meteorological radar and possible applications in the Navy are further investigated in the recently completed report "Meteorological Radar and Its Usage in the Navy." In the report, basic radar meteorology theory and meteorological information obtainable via radar are presented. The report indicates that Doppler radar information can be derived which is pertinent to fleet operations, such as precipitation, wind, wind shifts, and turbulence. Possible applications and implementations for operational purposes are presented. It is concluded that meteorological information derived from Doppler radar can provide valuable input to TESS(3) and the Battle Force Information Management Systems (BFIM) and Tactical Decision Aids (TDA).

Various aspects of sea clutter and its impact on weapon systems are also being examined. These include the integration of ocean wave spectral models and sea clutter models and the inclusion of breaking wave criteria into the clutter models.

TESS(3)

The Tactical Environmental Support System (TESS(3)) is a high priority project under program sponsorship of the Oceanographer of the Navy (CNO OP-006). As Technical Direction Agent for the TESS(3) project, NEPRF reports to the TESS(3) Program Manager at SPAWARSYSCOM. NEPRF is responsible for assisting in the preparation of the TESS(3) specifications and in monitoring the delivery of items from the contractors. Acquisition of the TESS(3) has been supported by the development of a Statement of Work, Type A Specification, and Source Selection Plan. NEPRF is scheduled to receive and install the second Engineering Development Model (EDM) of the TESS(3) in late 1988. After the initial acceptance test and evaluation, the EDM will be used for software development and testing. The TESS(3) is a system which employs non-developmental items (NDI) such as proven data communications, processing, and display technology in an integrated fashion to provide Navy tactical commanders ashore and afloat with secure, responsive, and endurable environmental support. Applications software programs developed and provided by the Navy will process data acquired from various sources to provide Battle Force/Group, Task Force, and ASW Operations Center (ASWOC) commanders with support which is tailored to their specific operational requirements. The TESS(3) is planned for installation on 44 ships and at 27 shore sites, and has an initial operational capability (IOC) of 1990.

No current operational sensor or weapon system is totally immune to the effects of the environment. The continuing evolution of higher technology weapon/sensor systems increases the dependence upon accurate, responsive meteorological and oceanographic support. The TESS(3) is designed to significantly improve the ability of Navy Command and Control System elements to acquire, process, and distribute tailored environmental support information so that it may be used as an effective force multiplier. Information is stored, ingested, processed and disseminated by the TESS(3) for atmospheric, oceanographic, weapons sensors, and mapping, charting and geodesy data. The data can be retrieved from climatological data bases, local sensors, satellite downlinks, or regional oceanography center data fields. Other interfaces which aid in the flow of information include: radioteletype, satellite communication system (SATCOM), Shipboard Meteorological and Oceanographic Observation System (SMOOS), Closed-Circuit Television (CCTV), and various generic interface ports.

More than sixty software applications packages provide various types of information to the user. The simplest product may be the display of environmental information such as tropical storm warning areas. The next level of complexity may be environmental data merged with equipment parameters such as the Search and Rescue program which takes into account the winds, seas and type of downed aircraft or boat. The most complex software packages blend environmental conditions and platform parameters into a tactical decision aid such as the surf forecast model which recommends optimum approach corridors for specific amphibious landing craft. Work was recently completed for application software programs for Aircraft Icing, Ship Ice Accretion, Aircraft Ditch Heading, and Interactive Multivariable Environmental Analysis.

An important goal of TESS(3) is the prediction of fog at sea. Towards this end, NEPRF is developing the Shipboard Obscuration Prediction System (SOPS), a multi-faceted approach to forecasting obscurations, principally fog, at sea. SOPS will include the Navy Over-Water Local Atmospheric Prediction System (NOWLAPS), a 1-D, shipboard forecast model for forcasting winds and thermodynamic structure in the planetary boundary layer. Another component of SOPS will be NEPRF's pioneering effort in artificial intelligence, an expert system which mimics a weather forecaster's analysis of the synoptic weather situation. These two components, along with unconditional climatology and perhaps a Model Output Statistics (MOS) prediction from central-site global and regional models, will be integrated to form SOPS, an automated tool to aid the shipboard forecaster. Another research effort in support of TESS(3) was the refinement of an overwater diffusion model to include both relative diffusion and meander. This diffusion model predicts the movement and dispersion of an aerosol cloud over the open ocean and provides the basis of the Chemical Weapon Hazard Forecast Program (CHEMFO). These environmental aids were developed to be run on Navy Standard Desk Top Computers and have transitioned into the Geophysics Fieet Mission Program Library (GFMPL) for operational distribution.

Conclusion

NEPRF's leading role in atmospheric research cannot be underestimated. It is the Navy's leading facility for the research and development of environmental products that provide invaluable support to operational naval forces both ashore and afloat. These efforts are concentrated in the areas of numerical modeling and weather prediction; weather forecast and analysis aids; and environmental effects upon weapon and sensor systems.

The future role of NEPRF is a constantly evolving one which is directed toward expanding R&D efforts toward more direct support of naval warfare areas such as strike warfare, anti-air warfare, and anti-surface warfare. A new thrust in the basic research (6.1) area will center on remote sensing of the planetary boundary layer of the atmosphere. Lastly, as the TESS(3) contract award becomes imminent, NEPRF's role as Technical Direction Agent will acquire increased significance. One of NEPRF's highest priorities will be to ensure that this revolutionary system provides the Navy with a quantum improvement in environmental support technology provided to operational forces.

Biography

Lt. Tim Dowding is a 1978 graduate of the U.S. Naval Academy. He is in the Restricted Line (Oceanography) branch and is a Research Officer at NEPRF. Currently, he is doing research on aerosol dispersion in the MABL and is also working on the TESS(3) project.

Unusual Clouds of Ionized Gas Discovered in Space

Astronomers at the Naval Research Laboratory (NRL), Virginia Polytechnic Institute and State University, and Mullard Radio Astronomy Observatory recently discovered that the ionized gas in our galaxy contains unusual cloud-like structures, as reported in the April 16 issue of *Nature* magazine. This discovery has far-reaching implications concerning the content of the Milky Way galaxy in which we live.

The measurements that resulted in the discovery of these ionized clouds were performed using an interferometer, a special radio telescope, located in Green Bank, W. Va. (The magnification power of the instrument is equivalent to being able to read a stop sign six miles away.) The interferometer is operated by the National Radio Astronomy Observatory (NRAO) for the U. S. Naval Observatory and NRL. The NRAO, which operates four radio telescopes in the United States, is funded by the National Science Foundation (NSF).

The researchers report that the newly discovered clouds are not like the typical clouds known to be in the galaxy. The Milky Way is generally believed to contain about 100 billion stars, which is roughly equal to the number of fine grains of sand in a cubic yard. It is also known that the galaxy contains a considerably fewer number of hot (20,000 degrees Fahrenheit) and cold (−370 degrees Fahrenheit) clouds of gaseous hydrogen and carbon monoxide ranging in size from 10 thousand to 20 million times the size of our solar system. The weight of these clouds ranges from two-tenths to 10 thousand times the weight of the sun.

The newly discovered clouds appear to be more numerous than stars and could be as small as the distance between the earth and sun (93 million miles). The weight of a single cloud is about that of an asteroid, which is negligible compared with our sun's weight. The research team reports that it is the small size and weight of these clouds that has made them almost impossible to detect until now.

The primary use of the interferometer has been a joint program between the USNO and NRL to measure the position of fixed objects in the sky with respect to an earth-based coordinate system. As part of that program, NRL astronomer Dr. Ralph Fiedler has been analyzing the brightness of 36 distant galaxies that were examined once a day from 1979 through 1985.

Dr. Fiedler reports that the ionized clouds could be a result of a growing network of material ejected in the explosions of supermassive stars known as supernovae. In principle, each explosion could produce many such small clouds. Dr. Fiedler is planning other experiments using the interferometer and other radio telescopes. He hopes that the experiments will reveal more information about these mysterious clouds and the role they play in our galaxy.

(R. Fiedler, NRL)

NRL-Developed Device Vital to pulsed-power systems

A team of plasma physicists at the Naval Research Laboratory (NRL) report that a unique Plasma Erosion Opening Switch (PEOS) has numerous application possibilities in addition to its use for Sandia Laboratory's Particle Beam Fusion Accelerator (PBFA II).

The applications for the PEOS include nuclear weapons effects simulation, production of intense electron or ion beams, pumping of high-power lasers, and other areas requiring very fast risetime pulses of high-power electrical energy.

NRL's Dr. Gerald Cooperstein, one of the principal investigators in the plasma erosion opening switch, and his staff report that the new device's capability to switch large electrical currents very rapidly in an inductive energy storage system, and thus multiply voltage and power, represents a significant advance in switching technology at high-power and high-energy levels. It can conduct currents of several megamperes for 100's of nanoseconds while closed and then open in 10 nanoseconds and withstand voltages of several megavolts without shorting. In comparison, conventional opening switches operate on much longer scales and withstand much lower voltages than the PEOS after opening.

Cooperstein states that although the present work at NRL on the PEOS represents a very successful demonstration of fast switching and output power gains at terawatt power levels and has become a "key element" in Sandia's fusion accelerator, there is yet much more research to be done. Additional work is aimed at further understanding the complex plasma physics involved in the operations of the PEOS so as to be able to increase the switch's conduction time, decrease its opening time and increase voltage holdoff. This work could lead to a new generation of high power, more compact and less expensive pulsed-power machines, thus allowing many more laboratories to study applications involving advanced pulsed power technology.

(G. Cooperstein, NRL)

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